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Heat from Abandoned Mines: Developing a Legacy

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A joint lecture between NEIMME and the GSL

The Institute held a joint meeting with the Geological Society of London in September 2018, with Dr Charlotte Adams giving a lecture entitled 'Can Abandoned Mines Heat our Future?'. In this article Dr Adams writes about how coal extraction from around 23,000 collieries across UK coalfields over the past century has left a legacy of flooded former mines. The water within these mines now represents a vast energy resource that has a valuable role in decarbonising UK heat demand.

The Rise and Demise of Coal

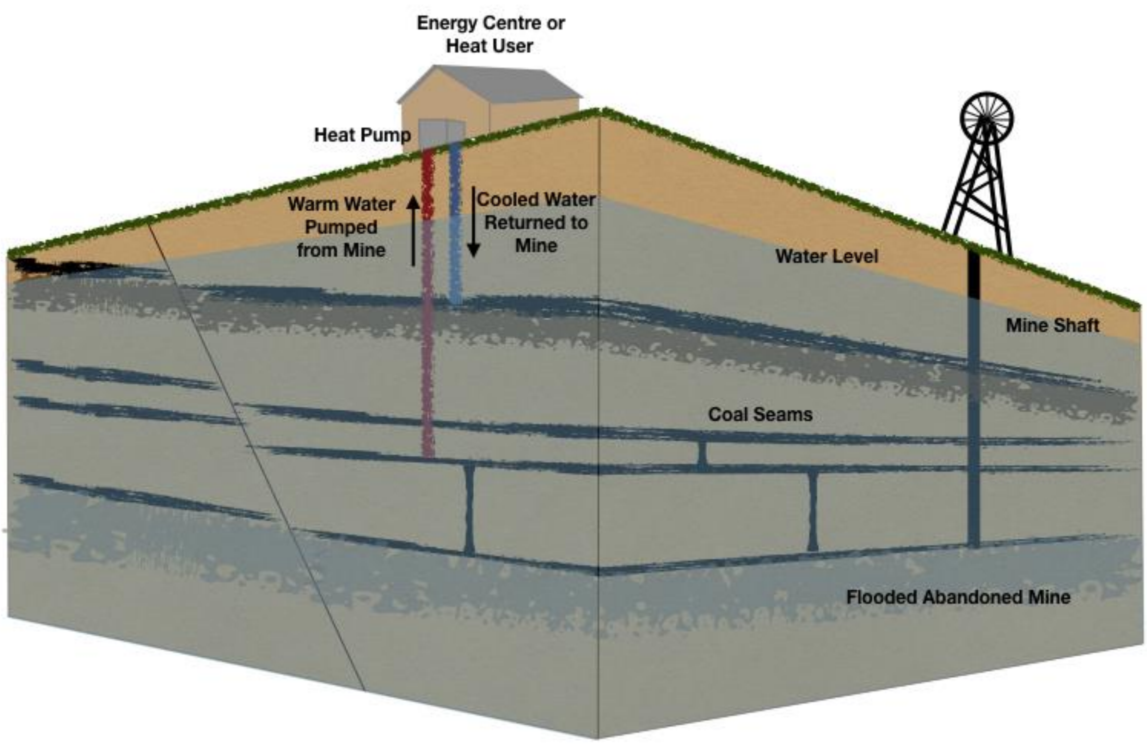
Over 15bn tonnes of coal were mined from the UK subsurface over the past century. This literally fuelled our economic and industrial growth as towns and cities grew due to the resources beneath them. Despite the immense wealth coal delivered, it is now regarded as a "dirty" fuel, (because of the associated CO_2 and other pollutant emissions) and is being gradually removed from our energy mix. The UK recently celebrated a period of 18 days where coal was not used for generating electricity which is the longest period without coal since the 1880s. Around half of UK electricity demand has been decarbonised over the past decade using a mix of nuclear and renewable energy generation (BEIS 2018). However, around half of UK energy demand is associated with the production of heat and most of this is consumed by the domestic sector. Natural gas supplies around 70% of heat but this leaves the UK in an uncertain position with respect to energy security. We have been a net importer of gas for over a decade which has created dependencies on other nations to maintain supplies.

Developing a Legacy

Since the closure of the UK's last deep mine at Kellingley in 2015, our abandoned mining infrastructure is largely forgotten. However people in former coalfield areas remain strongly connected to their mining heritage notwithstanding the fact that its decline has brought economic hardship and in some areas environmental damage. Yet the growth of towns and cities due to coal mining means that these areas now have an opportunity to repurpose this infrastructure and access the energy resources contained within the mines. The flooded mine shafts and galleries contain vast quantities of water at temperatures of 12-20°C. This temperature is too low to be useful for heating but it can be used direct to provide cooling and heat pumps can be used boost temperatures sufficient to provide hot water and space heating. Heat pumps are not a renewable energy technology because they require an electrical input but because each kW of electrical energy input should deliver a heat output of 3-4kW, heat is provided in an energy efficient way. Mine energy systems offer some advantages over individual closed loop ground source heat pumps. Firstly there is improved thermal recovery because they operate open loop and secondly, economies of scale can be achieved because they can deliver district scale quantities of heat meaning that clusters of hundreds of properties could be heated using a single mine and a few boreholes. Delivering this vision is challenging because it involves moving away from current energy supply arrangements that based upon circulating high temperature fluids. Developing mine energy systems requires changes to planning and building control polices that support development of low temperature energy systems.

Durham Energy Institute at Durham University has been undertaking national, regional and local assessments of mine energy potential for a range of applications under the auspices of BritGeothermal, which is a national research partnership for deep geothermal energy and the National Centre for Energy Systems Integration. This work includes assessing domestic residences, industrial developments and municipal buildings for mine energy systems. To assess the potential, it is important to understand the nature of the subsurface infrastructure and appreciate of how water quality can evolve during mine abandonment and also following periods of abstraction. Research by Nuttall and Younger (2004) has shown that following long periods of abandonment, water within mines can become highly stratified with better quality water generally lying above poorer quality water. Water quality may evolve once the workings begin to be pumped to deliver mine energy. Many minewaters contain iron which is a remnant of the interaction between the oxygenated minewater and pyrite within the coal (particularly high sulphur coals) and is the nemesis of minewater management. This challenge can be overcome by excluding air from any minewater heat pump system and keeping systems under positive pressure, which limits the dissolution of oxygen.

To calculate the potential of this resource, it is necessary to go back to the mine abandonment plans which are held by the Coal Authority. If there are no data available on coal volumes removed from each seam then the seam plan for each colliery is used to calculate the worked area. The seam thickness is then multiplied by the area to give the worked volume and hence void before subsidence. Although coal extraction leaves subsurface voids that remain long after mine abandonment, these voids will not remain exactly as they were at abandonment. Shafts were often filled with rubble from the demolished topside colliery infrastructure before being capped rendering many of no value for future water pumping. The floor of galleries and may "heave" and roof material may collapse leading to tunnels with partial blockages along their length. This means that the amount of remnant void space depends upon the mining method. Early 'room and pillar' mining involves working a grid leaving pillars of coal intact for roof support and mining the areas between. This was later replaced by longwall mining (first developed in Shropshire in the 17th Century) as a more efficient means of removing coal and led to many areas formerly mined by room and pillar method being reworked using longwall extraction.



Schematic Diagram of a minewater heat pump system

Longwall mining involves driving tunnels to the furthest extent of the mine then removing coal from the seam laterally whilst retreating from the workings. As longwall mining proceeds the overburden above the seam subsides producing "goaf"(collapsed waste). The implications for calculating the mine energy resource are that an area mined by room and pillar methods is assumed to have around 50% of the original void space remaining and for longwall mining around 20% of the original void space remains (Adams and Younger, 1999). These voids in effect have created an 'anthropogenically-enhanced aquifer' in which heat can be extracted from or reinjected to the large water volumes existing within the mine workings.

The potential for the flooded abandoned collieries of the UK to provide a source of heating, cooling and energy storage is huge. Around one quarter of UK homes overlie abandoned coalfields. The UK Coal Authority has estimated that abandoned flooded mines are estimated to contain around 2.2 million GWh of heat with an even greater potential for heat storage. This equates to sufficient heat for around 180 million homes (there are 34 million in the UK).

There are few examples of mine energy projects in the UK. Bridgend Council in Wales is currently developing a larger district heating system that will supply heat to around 150 homes. Lanchester Wines, have recently commissioned their mine energy project which delivers heat to their warehouses in Gateshead. This is understood to be the first commercial scale system in the UK. At Heerlen in the Netherlands, abandoned mines have been used effectively for over a decade to deliver space heating and cooling to around 200,000m^2 of mixed use new and retrofit buildings via a 7km heat network (Verhoeven *et al*., 2014). This project has promoted the economic improvement of a former deprived mining area whilst delivering low carbon heat because the money customers spend on heat is retained within the region rather than going to a major, national energy supplier

Meeting the Challenge

Development of mine energy systems also has the potential to promote the UK geothermal industry. Deep geothermal projects have struggled to develop due to the upfront capital cost and risks associated with drilling boreholes that are not guaranteed to flow adequate quantities of water for energy extraction. Consequently, the UK has only one operational deep geothermal heat scheme at Southampton that was developed in response to a national audit of the UK's geothermal resources in the 1980s prompted by the oil crisis.

Although abandoned mines are shallower, the temperature of water within them is cooler but because they are systems that are known to flow copious quantities of water, the development risk is reduced. Therefore the UK can be described as sitting above an extensive but yet to be commissioned heat resource. Mine energy has a much higher technology readiness level than other low carbon replacements for natural gas such as hydrogen. Heat pump technology is proven and the UK has a long experience of drilling in mining areas. The reason this resource is so underdeveloped is that a whole new approach to the licensing of heat is required. We also need to overcome risk averse attitudes to "untested technologies" (Banks, 2004). The fact the UK has had ready access to relatively cheap gas also explains the lack of UK geothermal developments. Further complexities associated with retrofit of heat exchangers and heat pumps, economic risks associated with difficulties in securing long-term contracts for heat supply and system maintenance, concerns over water quality and subsidence also hinder widespread development.

BritGeothermal is lobbying for changes to national planning policy, licensing and regulation of use of the subsurface to ensure that mine energy potential is considered when planning new developments. This group is also investigating the mine energy potential of a number of former coalfields and it is hoped that the new Glasgow Geothermal Energy Research Field Site (BGS, 2018) and a variety of industrial and council supported projects in north-east England will significantly reduce subsurface, geoscientific uncertainties and risks, raise awareness and stimulate the market for this low carbon energy source.

A New Research Facility

The British Geological Survey (BGS) is constructing and operating the UK Geoenergy Observatories on behalf of the Natural Environment Research Council. This is an ambitious £31 million investment that will develop and operate two subsurface research observatories. Funded by the UK Government Department for Business, Energy and Industrial Strategy, the Observatories will facilitate improved understanding of subsurface change beneath our feet. The Glasgow Geoenergy Observatory, currently being constructed, will focus on shallow, low-temperature mine energy opportunities using the flooded abandoned mine workings below the east end of the city. The other UK Geoenergy Observatory in the Ince Marshes area of north Cheshire will focus on improved understanding of the subsurface environment across a $12km^2$ area down to 1200m below ground. This knowledge can be applied to a range of energy technologies.

The Future?

Clearly the potential to develop our mining heritage as a future energy source is huge. The message that our abandoned mining infrastructure that was so hard won could provide a source of low carbon energy for the future is a very powerful one and offers a ready solution to the challenge of decarbonising heat.

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