Mine-water Energy Toolkit

Mine Energy and Heat Networks

Summary

Mine energy projects use mine-water contained in former coal mining sites to provide space heating and/or cooling via heat networks or individual building connections.

This section gives an introduction to the unique blend of opportunities and challenges offered by mine energy and heat networks.

Key Points

Mine Energy Introduction

1. After coal mines stop production, water that naturally occurs underground fills the network of seams, tunnels and shafts left behind from the mining process.
2. This water is naturally warmed by the temperature of the earth below ground level. The deeper the mine workings the higher the water temperature.
3. At around 200 metres below ground level, the temperature of mine-water is typically around 15°C. At this temperature, the mine-water can be used for providing both heating and cooling such as in 5th Generation District Heating and Cooling projects (see later description).
4. Energy is harvested for space heating when mine-water is pumped to the surface. The water's heat is extracted using a heat exchanger and the cooled water recirculated back into the mine.
5. Mine workings create voids into which boreholes can be drilled to extract mine-water to feed the mine energy scheme.
6. Former coal mines are often near to population centres that have a high energy demand, making the geothermal energy directly accessible to a potential market.

7. Geothermal energy from former coal mines has a relatively low environmental impact when the pumped water is returned to the mine workings after having its heat extracted.
8. It is a renewable source of energy and produces little to no greenhouse gases during operation, particularly if powered by green electricity.
9. The development of geothermal energy from former coal mines does present challenges. These include potential contamination from mining residues, the requirement for substantial upfront investment and regulatory and permitting complexities. In addition, the efficiency and sustainability of the energy production depend on the careful management of the water circulation process to prevent the cooling of the geothermal source.
10. Despite these challenges, the use of geothermal energy from former coal mines offers an innovative way to reclaim former industrial sites for renewable energy production, contributing to the global transition towards cleaner, sustainable energy sources.
11. The UK coalfields are divided into many 'mine-water blocks'.
12. Mine-water blocks are groups of interconnected flooded collieries that cover very large areas. For example, the Northumberland and Durham coalfields are divided into 41 mine-water blocks.
13. After coal mines are closed, water fills the workings (referred to as 'recovering) and keeps rising until it reaches its natural water level (referred to as recovered.)
14. In some mine-water blocks, mine-water has to be pumped and treated to prevent it from contaminating water courses either below ground or at the surface. Land can also be contaminated or flooded by erupting mine-water.
15. Mine-water levels in some mine-water blocks have risen by well over 100 metres since the mines were closed.
16. Mine-water often has a high chemical content that can cause significant environmental damage.
17. The mine-water blocks are managed by the Coal Authority and the Environment Agency or Natural Resources Wales to ensure that no environmental damage from mine-water occurs.
18. The Coal Authority keeps plans of UK mine workings. These vary in accuracy and so it is important for mine energy project developers and expert advisers to conduct their own investigations into potential mine energy locations.
19. The International Energy Agency (IEA) Geothermal Technology Collaboration Programme has set up an international expert group on mine energy which is run by the British Geological Survey (BGS), with some funding from UK Government.
20. The IEA has formed a mine-water energy expert group https://iea-gia.org/areas-of-activity/geothermal-heating-and-cooling/mine-water-geothermal-energy-group/

21. The IEA mine-water energy expert group is collating mine-water energy case studies. These currently include:
    - Lanchester Wines (Case Study)
    - Research facility – UK Geoenergy Observatory, Glasgow (Case study, Website)
    - Fraunhofer IEG Bochum, Germany (Case study, Website)
    - Heerlen City Cluster based Energy Scheme (Case study, Website)
22. The IEA mine-water energy expert group with BGS, Coal Authority and BEIS has also run three international symposia in 2021, 2022 and 2023. The recordings are available at https://iea-gia.org/workshop-presentations/
23. The IEA mine-water energy expert group has a blog that is available at: https://www.bgs.ac.uk/news/collaboration-progress-and-emerging-themes-in-mine-water-heating-cooling-and-storage/

Mine Energy Project Opportunities

Low carbon heat networks using mine energy offer significant environmental, economic, and social benefits, making them an attractive option for transitioning to a more sustainable and resilient energy system.

24. **Mine Energy – Case Study – Gateshead Mine Water Project**: The Gateshead Mine Water Project is the largest mine water heat network in Great Britain and one of the largest in Europe. See Appendix 12 for details.
25. **Mine Energy - a Strategic Asset**: Recognized as a strategic asset by the Coal Authority, the heat stored in former mine workings could potentially provide cost effective low carbon heating to some of the most densely populated areas in the UK
26. **Enhancing Future Prosperity of Former Mining Communities**: building new economic strength from mining legacy, thereby stimulating economic regeneration and reducing energy bills.
27. **Boosting Energy Security**: using abundant energy from mine-water to generate revenues and enable money to stay in the local former mining communities.
28. **Fostering Community Pride**: celebrating the contributions of miners over generations, restoring pride to the community.
29. **Driving Low Carbon Diversification and New Technology**: fostering opportunities for low carbon diversification, energy storage, and development of new technologies.
30. **Encouraging Research and Development**: enhancing opportunities for research, development across the renewables sector.

31. **Supporting Regional Economic Growth**: Raising Gross Value Added (GVA) per head in former coal mine regions - currently below the UK GVA average.
32. **Reducing Heating and Cooling Costs**: With localised control of renewable heating and cooling sources, energy costs and carbon emissions can be significantly reduced, while improving energy security.
33. **Supply Chain Opportunities and Training**: Integrating supply chain opportunities and training with the construction of mine energy infrastructure projects optimises local economic value.
34. **Developing Fifth Generation District Heating and Cooling (5GDHC) networks**: 5GDHC networks can potentially use heat stored in former mine workings to improve efficiency
35. **Large Scale Energy Storage**: large-scale storage of heating and cooling in mine workings provides opportunities for developing advantageous energy purchasing and supply contracts.
36. Quotations from the: **1922 Business, Energy and Industrial Strategy Backbench Committee - INQUIRY 2: Deep geothermal and Mine-water: Valuable new sources of low carbon heating. May 2022**
    - "Mine-water heating is a potential resource in all parts of the country with a mining heritage - the Midlands, South Yorkshire, North East, central belt of Scotland and Wales."
    - "There is a high correlation with the levelling up priority areas, and also a positive story in terms of using an old legacy carbon intensive industry for generating new, low carbon heat."
    - "Projects could bring jobs and growth as well as low carbon heat sources."
37. Quotation from Lee Anderson MP for Ashfield – May 2022
    - "As the UK transitions to Net Zero I firmly believe that geothermal energy from abandoned coal mines presents a perfect opportunity to heat communities throughout the old coalfield areas. Not only would this be a great way to produce an endless amount of heat at constant prices but it would also be a wonderful legacy to the mining industry

Mine Energy Project Risks and Mitigations

38. Risks resulting from former mining construction and operation include:
    - Subsidence – from workings and shafts
    - Mine gas leaks
    - Contamination from toxic waste
    - Contaminated ground water
    - Unstable spoil tips

39. Land contamination remediation strategies differ for each location and therefore expert advice and services are required.
40. Levels of contaminated groundwater in former mine workings fluctuate and can sometimes emerge at surface due to artesian pressure when not controlled.
41. Volatile Organic Compound (VOC) contamination is common on former coal mine and other brownfield sites.
42. A shaft or any holes drilled into workings can create pathways for contamination down and also up.
43. It is sometimes necessary to create corridors of uncontaminated ground when levels of sulphate and other contaminants compromise construction work such as by corroding materials.
44. Old mine shafts are often difficult to locate and may not have been 'capped'. This creates subsidence risks.
45. Many former shafts have been in-filled but not necessarily to a safe standard resulting in the risk of collapse.
46. For any residential construction on former colliery sites, contaminated land must be prevented from potentially contaminating domestic areas – i.e. by being removed or sealed.
47. Shafts and 'breather shafts' all need to be avoided when laying pipework for heat networks. Risks include subsidence and negative pressure.
48. Hot works close to shafts are to be avoided due to potential ignition of any escaping gases. A 'Mine Gas Risk Assessment' must be submitted to the Coal Authority alongside the Mine-water Heat Access Agreement application – see the Licenses and Permissions section of the Toolkit for more details.
49. Unpredictable hydraulic behaviour - factors such as collapses, shafts, dams, and fracturing can significantly affect the hydrogeological behaviour, making it difficult to predict. Conventional numerical modelling approaches should be used with caution, although network modelling approaches have shown potential.
50. Another issue is inadequate yield and injectivity, which can limit the thermal output of the system. This can be related to encountering open mine voids, unexpected hydraulic behaviour, or clogging of recharge boreholes due to chemical or biological factors.
51. The management of dissolved gases in mine-water used in MWG systems is critical to prevent clogging, scaling, odours, asphyxiation, and corrosion. Contact between oxygen and anoxic mine-water containing dissolved ferrous iron or manganese can lead to oxidation and precipitation of these substances. Degassing of excess CO_2 can increase pH and promote precipitation of

carbonates and hydroxides. Dissolved methane and hydrogen sulphide can also be present and pose risks if not controlled properly.

52. Clogging and scaling of pipes, wells, and heat exchangers can occur due to increased water velocities and turbulence caused by pumping. Particulate matter and ochre (iron oxide) precipitation can restrict flow rates and reduce system efficiency. Corrosion of metallic components is another concern, especially in highly saline, reducing, or sulphide-rich mine-waters. Different mechanisms of corrosion can occur depending on water chemistry and metal types.
53. Mine-water treatment is often required before discharge in open systems to prevent contamination of surface water. Treatment methods include passive and active techniques to remove iron, manganese, salts, and other problematic parameters. The impact of temperature changes on the treatment process needs to be considered.
54. The specific challenges and treatment requirements may vary depending on the regulatory standards and the characteristics of the mine-water in different regions.
55. A summary of the risks associated with mine energy projects is included in:

“**A Review of the Performance of Mine-water Heating and Cooling Systems**

David B. Walls 1,*, David Banks 2 , Adrian J. Boyce 3 and Neil M. Burnside 1

Energies **2021**, 14, 6215 28

PLANNING

- Excessive up-front uncertainty and risk
- Permitting / regulatory issues (intertia, numbers of authorities, issues with deviated drilling and land ownership)
- Lack of appropriate thermal demand in mining areas
- Inadequate specialist input (e.g. chemistry, hydrogeology)
- Uncertainty in long-term availability of resource (especially pumped mine waters)
- Difficulty in identifying workable management and ownership models
- Lack of consumer confidence

CONSTRUCTION

- Unpredictable and excessive drilling costs (e.g. excessive casing to penetrate non-targetted mine voids; verticality; directional or deviated drilling)
- Not encountering mine voids as expected
- Unpredictable hydraulic behaviour of mine workings

OPERATIONAL

- Dissolved gas management (methane, hydrogen sulphide, carbon dioxide, oxygen, radon)
- Scaling and clogging of pipes, wells, heat exchangers (often ferric oxyhydroxide or ochre). Particulates.
- Decline in yield or injection capacity
- Corrosion of instruments, heat exchangers, pumps, pipes (salinity, sour gases, reducing conditions)
- Treatment of water prior to discharge (in some cases)
- Changing minewater chemistry, risk of pollution
- Thermal feedback within well doublet. Depletion of thermal resource. Thermal interference with/from adjacent minewater geothermal system.
- Vandalism

ECONOMIC

- High upfront risk translates into high capital cost
- Excessive pumping costs, if mine water deep
- Spiralling maintenance costs, especially if lack of functioning market for maintenance contractors
- Competition from cheaper alternative energy sources
- Increasing electricity costs (water and heat pumps)
- Ongoing water treatment costs (some systems)

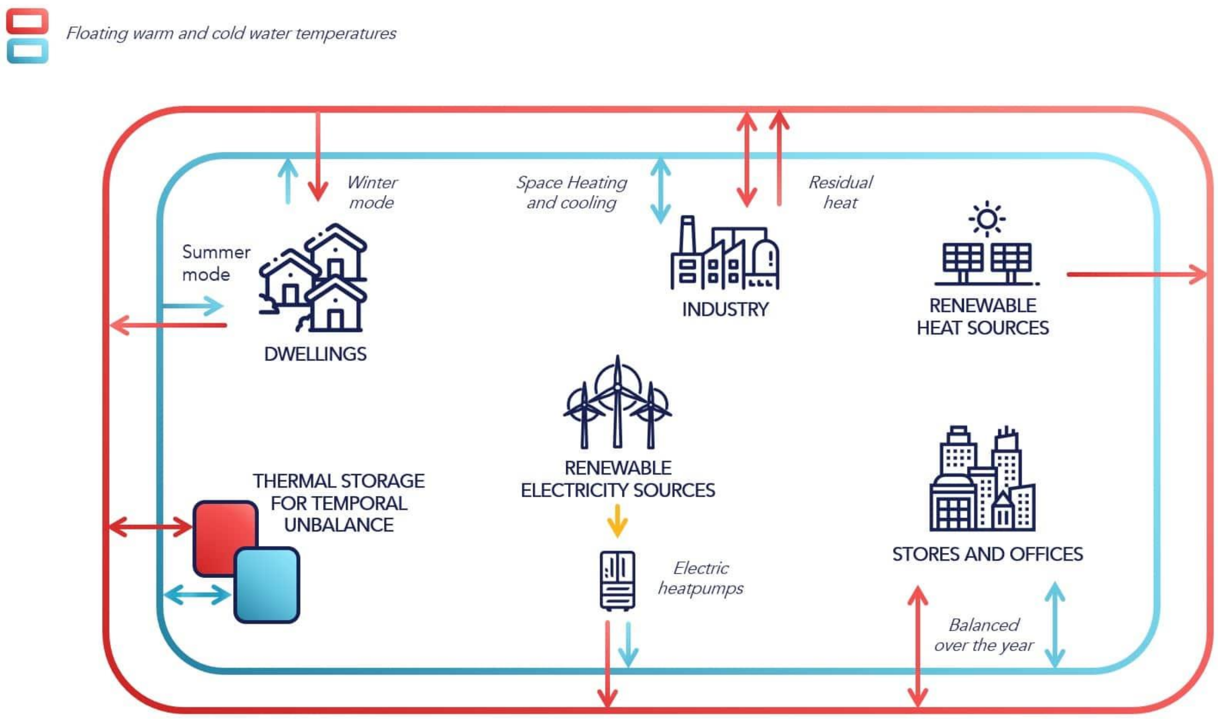
Heat Networks

Low carbon heat networks, also known as district heating, offer a variety of benefits which include:

56. **Environmental Benefits:**
    - *Reduced Carbon Emissions:* low carbon heat networks using mine energy can significantly reduce CO2 emissions compared to conventional heating systems.
    - *Promotion of Renewable Energy:* The commercial case for mine energy projects is significantly enhanced when powered by local electricity from renewable sources thereby encouraging the development of integrated renewable energy infrastructure.
57. **Economic Benefits:**
    - *Cost-Efficiency:* Heat networks can be more cost-effective than individual heating solutions as they can achieve economies of scale, reducing the cost per unit of heat delivered.

- *Energy Security:* By using local energy sources such as mine energy, low carbon heat networks can increase energy security and resilience against fluctuations in energy prices.
- *Job Creation:* The development, installation, and maintenance of heat networks can stimulate local economies by creating jobs.

58. **Social Benefits:**
    - *Reduced Fuel Poverty:* By lowering the cost of heating, low carbon heat networks using mine energy can help alleviate fuel poverty.
    - *Improved Air Quality:* By reducing the use of fossil fuels for heating, low carbon heat networks can improve local air quality, benefiting public health.
59. **Operational and Infrastructure Benefits:**
    - *Flexibility and Scalability:* Heat networks can be expanded or contracted to meet changing demands for heating and can make use of a wide variety of heat sources including mine energy.
    - *Integration with Smart Grids:* low carbon heat networks using mine energy can be integrated with smart grids, allowing for sophisticated management of heat demand and supply, further increasing their efficiency.
    - *Fifth Generation District Heating and Cooling:* 5GDHC are innovative heating and cooling networks that meld well with mine energy sources because typical mine-water temperatures are compatible with providing both heating and cooling – see details of the mine energy project in Heerlen, The Netherlands.



5GDHC Image from Mijnwater B.V. – Heerlen, The Netherlands