Mine-water Energy Toolkit

Hydrogeology and Geology
Summary
This section of the Toolkit provides an introduction to the hydrogeological and geological factors that impact mine energy schemes. Experts have written papers that cover these fields in great detail, a selection of which are included in the **Toolkit library**. A detailed understanding of hydrogeological and geological conditions at each mine energy project site is critical to optimising the opportunities and mitigating the risks. Expert hydrogeological and geological input is vital for every mine energy project.
Key Points
Opportunities 1. Underground mine tunnels can serve as conduits for geothermal fluid circulation, facilitating heat exchange. 2. Geological structures, such as faults or fractures, alter the permeability of the subsurface which can both improve and obstruct the flow of mine-water and therefore the efficiency of geothermal systems. 3. Access to geological data from mining activities can aid in site characterisation and geothermal resource assessment.

4. Underground mine voids can potentially be used as heat storage reservoirs, providing thermal energy storage capabilities.

Challenges

5. Geological conditions significantly alter borehole design and drilling techniques.
6. Timescales for drilling vary considerably depending on depth, diameter and geological conditions.
7. Predicting the geothermal resource potential and performance of mine energy projects prior to investigation is challenging due to the complex geological conditions and the current limited understanding of the thermal behaviour of mine-water.
8. The availability and quality of geological data from mining activities varies, requiring additional site characterisation investigations.
9. The hydraulic characteristics of each mine energy project location are uncertain until tested, usually via borehole drilling and pump testing.
10. Interconnections and obstructions in mine workings significantly impact hydraulic characteristics and therefore the design and operation of geothermal systems.
11. Collapsed zones and fracturing can create geological complexities and affect the stability of the underground infrastructure.
12. Clogging and scaling of pipes, wells, and heat exchangers due to mineral precipitation and particulate matter can impact system performance.
13. Metallic components of energy infrastructure can be corroded by mine-water, depending on the chemical make-up of the mine-water
14. Dissolved gases, such as oxygen, methane, and hydrogen sulphide, can result in clogging, scaling, and safety risks.
15. Treatment of mine-water for contaminants, such as iron, manganese, or salts, is typically necessary before discharge to controlled waters. This may not be necessary if the discharge is back into the mine workings, provided there is no significant change in water quality (this is an area on which Natural Resources Wales will advise).

Further Considerations

16. The hydrogeology of former coal mine areas is complex because aquifers and constructed coal mine infrastructure such as seams, roadways and shafts are interconnected.
17. Water quality plays a significant role in the operation of mine energy systems. Mine-water can have high concentrations of dissolved salts, minerals, and sometimes even heavy metals. The chemical composition of mine-water can cause scaling, corrosion, and other issues that could lead to reduced efficiency, or even damage to the system. Therefore, regular water quality assessments are a crucial part of operation, maintenance and commercial plans.

18. In cases where the mine-water has a particularly aggressive chemical composition, certain mitigation measures may need to be taken. One of these could be the use of materials that are more resistant to corrosion for the heat exchangers. For example, if the water quality is poor, shell and tube heat exchangers are less prone to corrosion than plate heat exchangers. Plate heat exchangers made from titanium may be a viable option given this metal's high resistance to corrosion. However, the use of such materials can significantly increase costs, so a careful analysis must be conducted to balance system longevity and cost-effectiveness.
19. Other mitigation strategies can include the use of anti-scaling chemicals, or even water treatment systems to improve the quality of the mine-water before it reaches the heat exchangers. Any chemicals used need to be approved by regulators for reinjection into mine workings.
20. In cases where there is a risk of the mine-water being contaminated with harmful substances like heavy metals or radon gas, it may be necessary to implement containment and treatment procedures to ensure these substances do not pose a risk to the environment or human health.
21. The preferred approach to the management of mine-water contamination is to return the abstracted mine-water via a reinjection borehole into the mine workings after heat extraction.
22. The temperature of mine-water varies significantly based on the depth and the specific geothermal gradient of the area. This impacts the choice of heat pump technology and the overall design of the system. At the depth of former UK coal mines, mine-water temperatures are typically between 12°C and 25°C.
23. Ochre is a precipitate that forms as a result of the oxidation of iron present in mine-water. Ochre is typically an orange-red or yellowish material and it can accumulate on different parts of the geothermal energy system, especially on the pumping infrastructure.
24. The accumulation of ochre can significantly reduce the efficiency of the pumps and even lead to equipment failure if not properly managed. It can clog pumps, pipe systems, and heat exchangers, reducing the flow rate and the effectiveness of heat transfer. This can reduce the overall efficiency of the mine energy system and increase operational costs due to more frequent maintenance and potential equipment replacement.
25. To mitigate the impacts of ochre buildup, several strategies can be implemented:
    - **Regular Monitoring and Maintenance**: Regular checks can help identify early signs of ochre buildup, allowing for preventive maintenance and cleaning before the buildup becomes problematic.
    - **Water Treatment**: Various water treatment methods can be used to remove or reduce the iron content in the mine-water before it reaches the pumping infrastructure. This can

involve chemical treatment, filtration systems, or aeration to precipitate the iron before it reaches critical system components.

- **Material Selection**: Choosing materials that are less prone to ochre adhesion can help reduce buildup. Certain coatings or treatments can also make surfaces less conducive to ochre attachment.
- **Controlled Oxidation**: In some cases, controlled oxidation of the iron in the water can be conducted in a separate basin or treatment system before the water is pumped. This allows the ochre to be removed before it enters the system.

26. If not properly managed, ochre can also have negative environmental impacts. The discharge of ochre-laden water at the surface can pollute waterways and harm aquatic ecosystems. This is mitigated by ensuring that mine-water energy project developments meet the requirements of water discharge licenses.
27. Ochre management is an important inclusion into operational plans to assure delivery and maintenance of an efficient, reliable, and environmentally responsible mine energy project.

Further Sources of Information and References

28. https://www.bgs.ac.uk/geology-projects/uk-geoenergy-observatories/

Key Actions

Action	Timeline
1. Engage and/or Procure appropriately qualified and experienced hydrogeological and geological expertise. 2. Liaise throughout with the Coal Authority Permitting and Mine Energy Advisory Services Teams. There are charges for some of these services.	From inception and throughout the project