LOw Carbon After Life: sustainable use of flooded coal mine voids as a thermal energy source - a baseline activity for minimising post-closure enviromental risks

Research Fund for Coal & Steel

LoCAL Deliverable 3.2

Pathways to Market

WP number	**WP 3**
Partner responsible	**Nottingham Trent University**

NTU

Deliverable 3.2

Pathways to Market

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Introduction

This task analyses the possibilities of market implementations. Such analysis intends to bring research and scientific results of LoCAL projects closer to market. We have used established Technology Readiness Level (TRL) appraisal tools, widely used in the EU, to evaluate all the technical results arising from the project, to establish how far up the TRL scale they have reached during the life of LoCAL. As anticipated, all LoCAL outputs have ranked above TRL 5. For systems at TRL8, the industrial partners have participated in a focused workshop on final delivery to market (TRL 9). To support generic development, an on-line survey was developed for companies, students/academics, local councils and the public to capture their knowledge and understanding of the technology to develop a comprehensive commercialisation plan to TRL9. Hence, the industrial partners will then be empowered to take forward the advancement of all outputs to TRL 9.

1. Technology Readiness Levels

Technology Readiness Levels (TRLs) are indicators of the maturity level of particular technologies. This measurement system provides a common understanding of technology status and addresses the entire innovation chain. There are nine technology readiness levels; TRL 1 being the lowest and TRL 9 the highest. The details of each level is as given below.

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

The potential sites to install the mine water based energy system were identified and case studies were carried out at these sites in line with the TRL 3 and later, pilot plants were constructed at Poland, Spain and UK. In Poland the pilot plant reached the TRL 7, to demonstrate the technology in relevant environment. In UK, pilot plants at Caphouse and Markham, the pilot plant systems demonstrated the operations in an industrial environment and successfully proved that the technology is ready for commercial roll out. In Spain, the pilot plant was commercially rolled out to the customers and it showed the way forward for the complete commercialisation of the technology. Figure 1 identified the TRL levels of the case studies within the project.

Through the LoCAL project, for the purpose of commercialsation, an online survey was conducted to get the feedback from the key stakeholders: Companies, Policy Makers and Consumers. A workshop was organised where key stake holders participated to discuss about the opportunities and hindrances to the commercialsation of the technology. Pilot plants were built and tested in actual industrial environment.

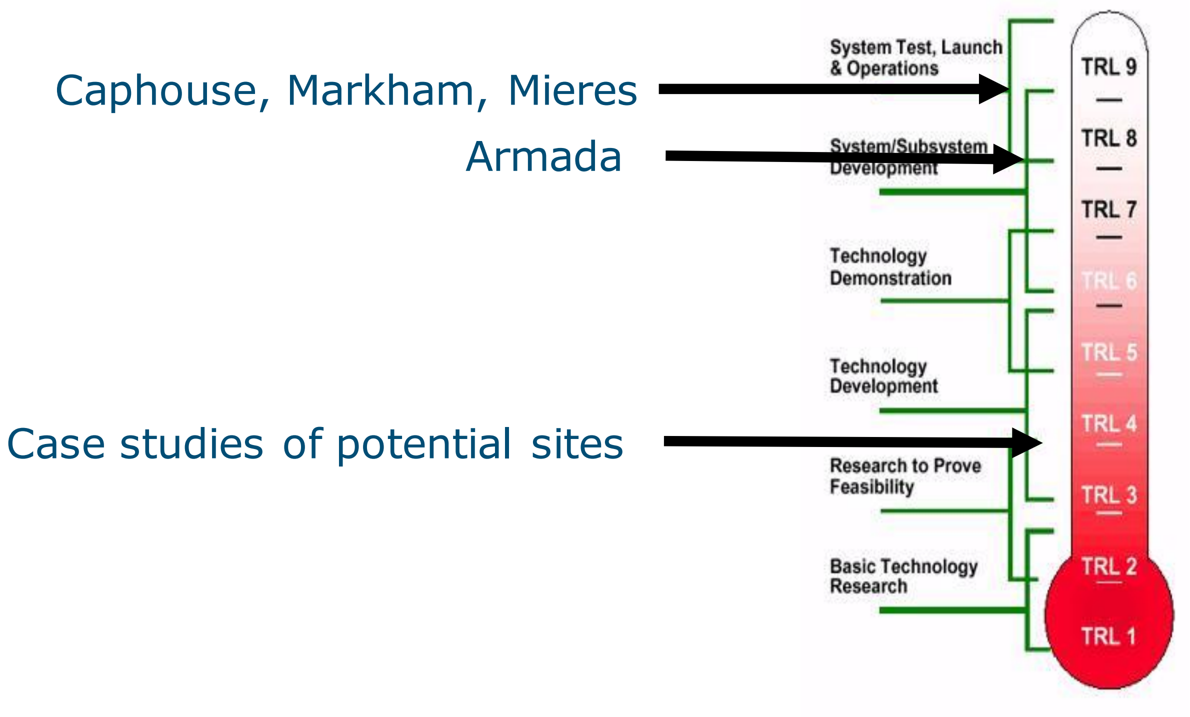

Figure 1: Level of TRL reached by the pilot plants across the LoCAL project.

2. Workshop

A Workshop for pathway to commercialization on 'Challenges and Opportunities of using water from Flooded Coal Mines for Heating and Cooling applications' was organised at Nottingham Trent University, presided by Prof. Amin Al-Habaibeh. The workshop has included participants from a wide range of sectors including Nottingham City Council, Alkane Energy Ltd, The Coal Authority, Clean Rivers Trust, Gannet Ltd, UK Community Works CIC (Community Works) and energy researchers.

Professor Amin defined the topics of this workshop that needed to be discussed which are:

1. What are the challenges towards commercialisation to enable the technology to be widely implemented? (with respect to local council, energy companies, installers, users, environment, planning permission, etc.)

2. What are the commercial benefits that can be obtained from using mine water for heating/cooling?

The workshop started by an introductory presentation given by Prof. Amin Al-Habaibeh where he outlined the project's background, ongoing work and partners. He mentioned various important points which can be summarised as follows:

1. Mine water could offer considerable benefits since this kind of water remains at constant temperature regardless of the outer environment. Therefore, the extracted energy could be very stable during the year.

2. Mine water can be used to either heating or air conditioning applications.

3. In the UK, there are seven locations that operate with this technology. Two of the coal mines within LoCAL project: Markham and Caphouse. At the Markham and Caphouse sites, monitoring systems have been implemented to evaluate the COP and performance of the heat pump schemes. Markham site, near Bolsover (on the M1 junction 29A), provides heating from mine water to two buildings. In Markham scheme, both gas engine and heat pump are being used. On the other hand, Caphouse site, near Wakefield, at The National Coal Mining Museum of England where visitors can go underground and see the mine in this location. Open loop and closed loop systems are tested for this location.

Figure 2: The workshop: Pathways to Commercialisation of energy from flooded coal mines.

Presentation: Accessing Geothermal Heat and Storage

Mr Jeremy Crooks: The Coal Authority (UK)

The Coal Authority operates over 70 mine water treatment schemes across the UK and treats around 100 billion litres of mine water per annum to protect the environment. Mr. Jeremy Crooks, principal innovations manager in The Coal Authority, also gave a presentation discussing the importance and the benefits of mine water technology. Mr. Jeremy showed some interesting facts about the coal mining technology:

- In the UK, coal mining technology programs pump nearly 112 million mega litres per year of water. 34% of this water is potable, 38% for agricultural and 28% brackish.
- This technology has the potential to generate 63 megawatts of heat per year.

Water contamination with metals and chemicals is a very crucial issue in the mine technology. The authority's job is to make sure the water is clean when it comes to the surface and then decide if it has any benefits. Therefore, Jeremy focused mainly on water treatment schemes. Basically, they have so far four active water treatment schemes, one of them is Dawdon mine water treatment station in County Durham, England. The aim of this station is to prevent irreversible pollution of the East Durham aquifer by iron and chloride rich mine water. Three process streams have been installed to treat up to 150 l/s of water.

The ambition is to expand this technology to provide water and heat to residential, commercial, industrial, horticultural, aquaculture and raising the awareness of the heat benefits extracted from coal mine water.

Many Mine water projects in Europe are being operated that aim to demonstrate how the geothermal energy stored by mine water can be used as a safe and ecological way to heat buildings, e.g., Heerlen (Holland), Bottrop (Germany) 2018, Rostock (Germany).

Renewable Energy:

Jeremy talked also about the potential of water mine technology for the use of renewable energy. Renewable energy sources usually include solar energy, wind, hydro. Large numbers of coal mine schemes will benefit from the use of renewable energy sources when this power is used on site.

Energy efficiencies:

Strategies for developing an energy efficiency programme for this technology include: reduce pumping energy, demand and tariffs.

Mine water treatments future scheme in the UK follows the design route of small footprints: low whole life cost, low carbon footprint, income generation schemes which are the ultimate ambition of the innovation programme.

Finally, Mr. Jeremy concluded his presentation by stating the aim of his team at the Coal Authority, which is mainly finding opportunities for this work to make it commercially viable.

Figure 3: A group discussion during the workshop

3. Group Discussion- All Participants

All participants were divided into four groups to share ideas and discuss the challenges and opportunities of this technology based on their expertise and knowledge background.

3.1 Main opportunities of the technology

One of the main opportunities is develop a better peak demand efficiency, which should be state sponsored by the governments within the EU. The technology also is efficient when compared with standard air heat pumps, due to lack of fluctuation in temperature and the integration of heating and cooling processes. There is an opportunity in many EU countries, including the UK, because the water is pumped in many cases for environmental and practical reasons, hence the most expensive part of the technology is already paid for. The technology is suitable for low temperature district heating. In the UK the Coal authority is leading on some initiatives to expand the use of the technology. Data Centres and the need for cooling makes the water from flooded coal mines a very suitable technology for use in cooling. The technology also allows for improved and localised energy control and reduces strain on national infrastructure. The technology is capable to be integrated with a variety of heat sources and with stratified hot water tanks. The technology is simple and has a long term benefits with providing a resilience infrastructure. The technology is adaptable and can be modular to a wide range of applications. It is characterised by low noise and small size infrastructure. Mine water can be available away from rivers and seaside, creating an opportunity for 'midlands' regions. Also, EU countries has significant number of coal mines, creating high availability of the technology. The available data about coal mines, makes it possible to calculate the benefits of the technology in different locations. If the governments provide a system for smoothing the planning pathway with well-structured steps, this will encourage the commercial sector to invest in the technology. The technology will encourage sustainable development and long term commercial cost savings. It forms a potential revenue scheme for energy companies and developers. The technology can save carbon emission and energy and support the compliance with EU Energy Efficiency Directive (2012/27/EU) (ESOS Regulations in the UK). The technology can be supported and policed locally. The technology could help reducing energy poverty and support local councils to meet development goals. It is possible to adopt technology for seawater and river water. This will allow investors to expand the technology in wider locations. The technology could be integrated with renewable energy (such as solar PV).

3.2 Main challenges of commercialisation

'Champions' are needed to lead the way. For example, Barredo coal mine (Oviedo) was possible because of the determination and the 'championship' of the organisations and people who led on it. Lack of investment is one of the main challenges to support the infrastructure. It is still not a well-known or understood technology for many consumers or companies to invest in it. More effort is needed in this part. There cultural issues as far as the technology is concerned, particularly with the dependence on gas boilers in most buildings for heating, particularly in the UK. There is a lack of clear model to follow on all stages and on the long term. There is variation in infrastructure and running costs and the breakeven models. For example, low temperature district heating models are not well understood in many regions by customers and house developers. The high cost of infrastructure, would prevent small companies and developers from accessing the market due to the payback period. Difficulties of integrating different organisations/structures in one project such as local councils, unions, and private sector. Complex or not well understood regulations and permissions on the short and long terms. Community objections to not well understood technology. Lack of assurance regarding the stability of government policies in the EU or a clear subsidiary of the system in most EU countries. Operating cost, particularly maintenance, could be high in some situations.

The technology only possible for areas with flooded coal mines, which makes it suitable for special locations only, particularly with water not at high depth. There is a need to improve public awareness. Cost of pumping is dependent on the depth of water, which could create variability in the system. Selling the product is complex, because can only be done locally via local district heating systems. Many planning hurdles exist and simplicity is still needed.

There might be issues associated with the maintenance frequency of the system. It can be easily approved for non-residential buildings, including commercial, industrial, and office buildings.   However, it acceptance by local planning authorities for residential dwellings needs to be supported by government organisations and local councils. Developing strategies to attract investments could help commercialise such systems. Legal issues are not well understood.

Figure 4: Panel discussion and the way forward for commercialisation.

3.3 Further Panel Discussion

There is a need to develop clear models and case studies for government organisations and businesses, such as Barredo coal mine (Asturias), see Figure 5. It is a case study where large scale system is developed. But the cost of infrastructure could be high for pipes and district eating, therefore, there is a need to engage local councils or government organisations in the EU. Otherwise, the cost of the initial infrastructure would be too high to be developed by small or medium size energy companies. Such case studies can play a key role in convincing developers, local authorities and funding organisations with the technology. It is a source of renewable green that is Load balancing. The technology is sustainable and can reduce carbon emission. There is potential source of income for developers. But social effect has significant influence on the technology. Because the paperwork and licenses needed are the same for small or large schemes, it is more efficient to have large scheme systems. Otherwise, the overheads will be too high.

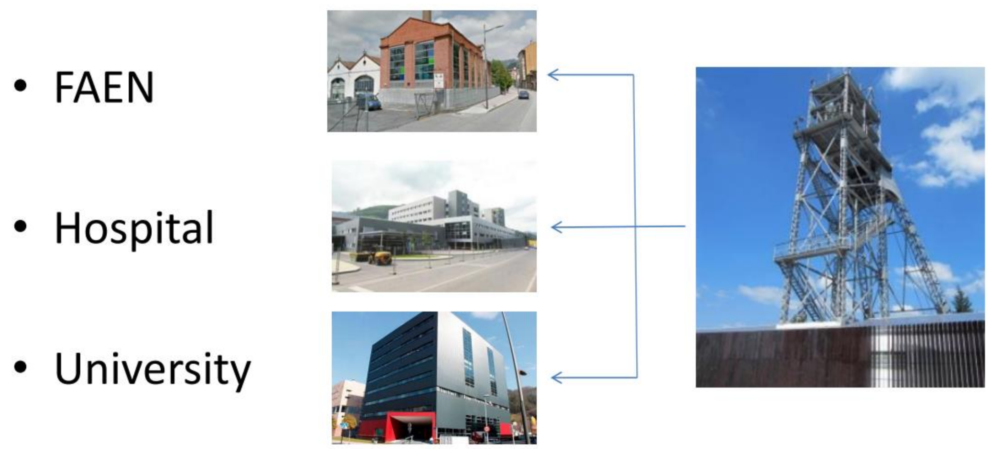

Figure 5: For pathway to commercialisation, Barredo mine (Asturias) is an ideal case study to be used (TRL9).

Cultural issues of designers and building services engineers who are not familiar with the technology or 'play safe', can prevent such technologies from developing at a high rate. Users don't understand the technology and hence there is a need for public engagement. Caphouse: could be used to heat the museum, but needs investment that they don't have and it is unknown technology for many people. For Katowice: there are small systems running there but for ARMADA there has been delay due to lack of awareness of the benefits and complexities within the legal/admin issues. But more importantly legal issues are not well understood. If drilling is needed, this will be a huge cost for many organisations to absorb.

4. Online survey

An online survey was carried out. The survey had 4 different questionnaire targeting 4 different audiences (energy companies, local councils, consumers and students/academics). In total 28 companies responded, 16 local councils, 85 students/academics and 40 from the general public. The objective was to see that if further and wider improvement of the awareness of the technology is needed to enhance the pathway to commercialisation on the long term. The results found indicate that more efforts are needed to educate students/academics and the public about the technology to enhance the commercialisation on the long term. However, the results show that most of local councils and energy companies are aware of the technology. From the survey (see Figures 6-9) it is clear that the majority of the energy-related companies are aware of the possibility of using the mine water as an energy resource. Majority of the local councils who influence the general decision making were also aware of the technology of using mine water as an energy resource. However, the survey showed that the general public which includes customers and general researchers/students were not aware of the technology of using mine water as an energy resource. This is bit concerning, as without the awareness about the technology, it would be difficult for the companies to convince customers to go for this technology without a clear long term strategy.

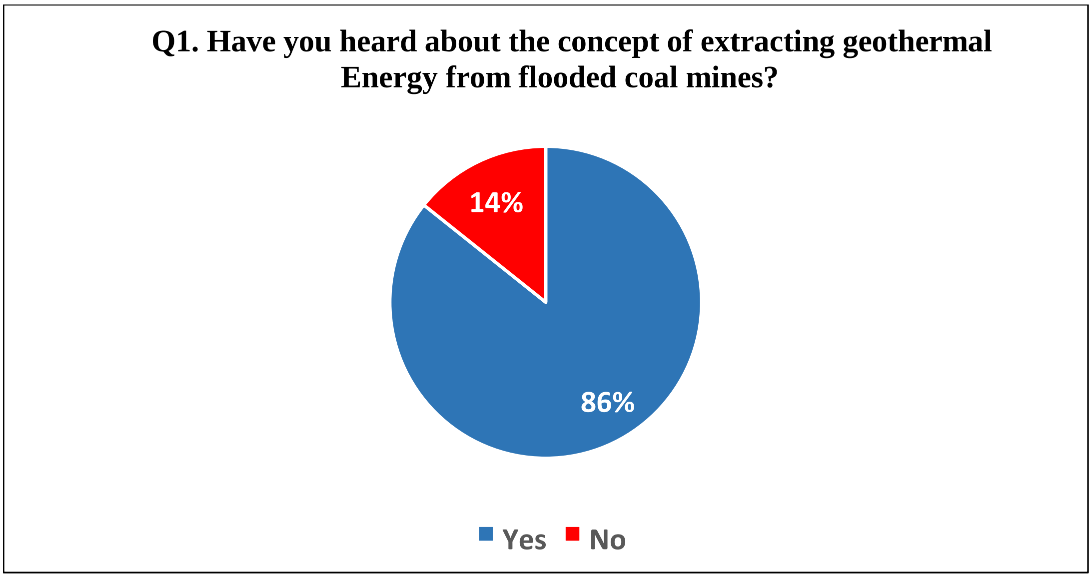

Figure 6: Survey regarding the Technology awareness among the energy related companies

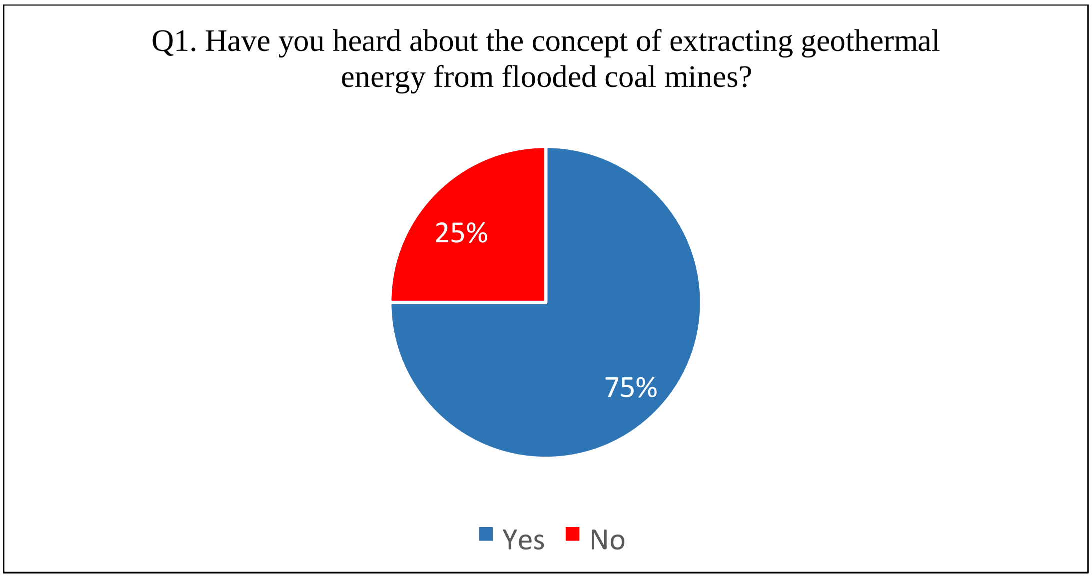

Figure 7: Survey regarding the Technology awareness among the local councils

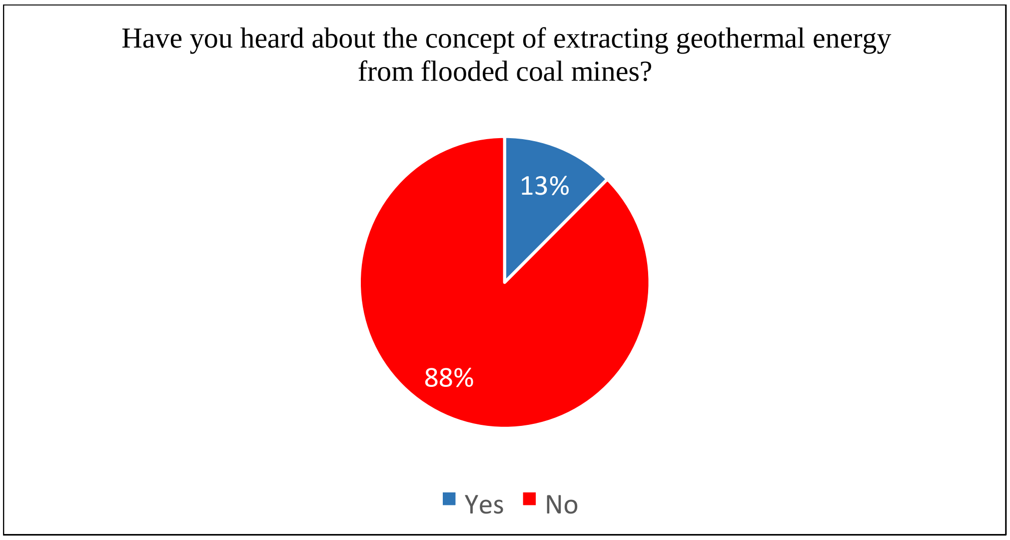

Figure 8: Survey regarding the Technology awareness among the general public

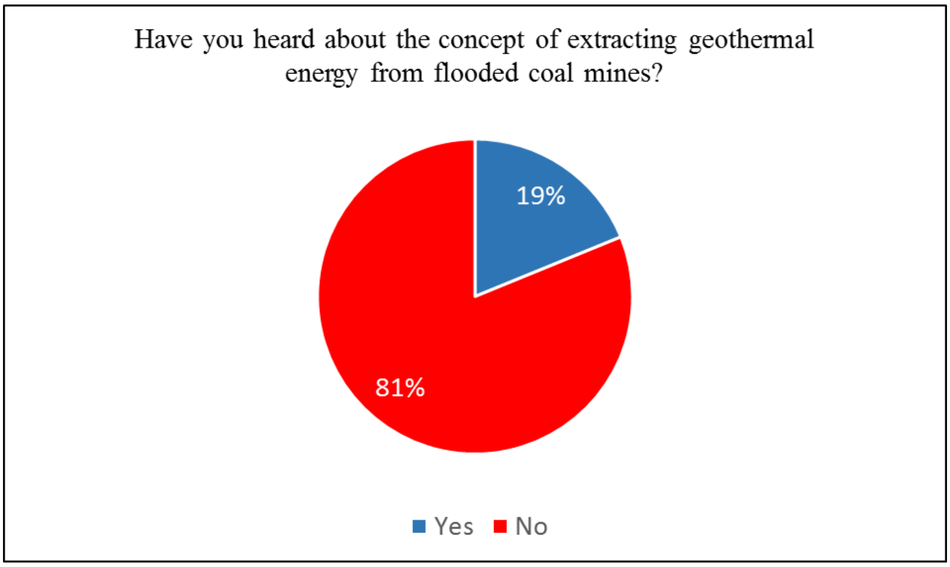

Figure 9: Survey regarding the Technology awareness among students and academics.

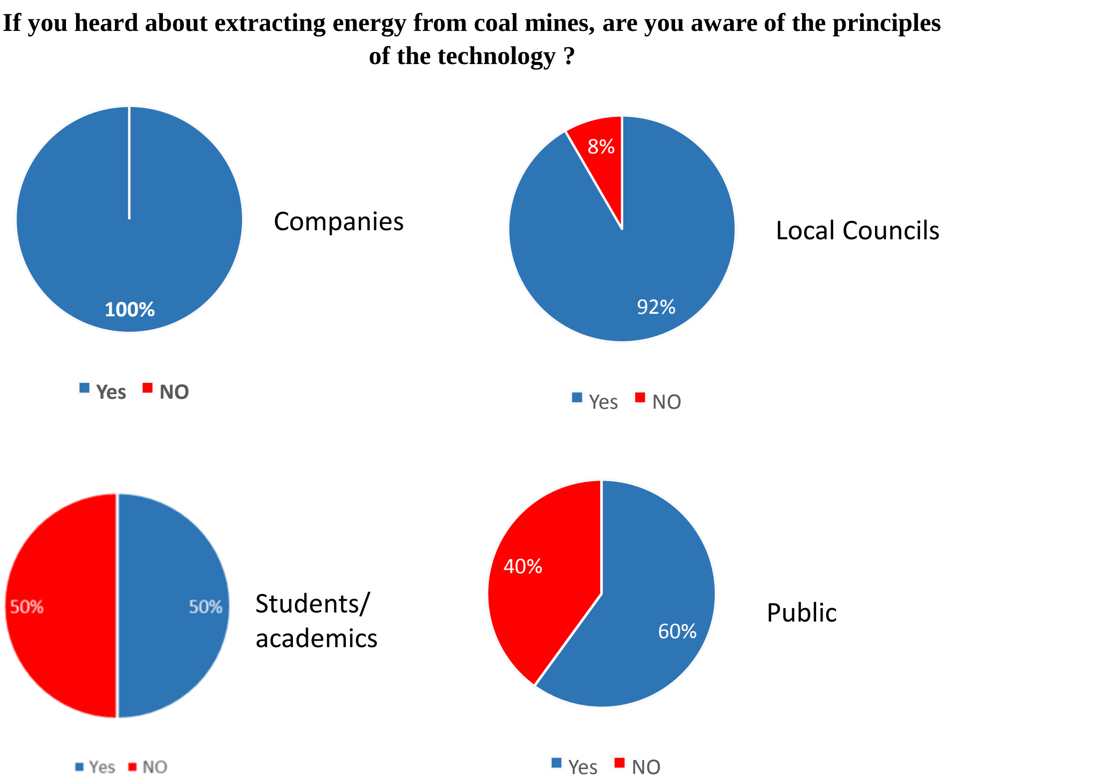

Figure 10: Awareness of the technology among the respondents who have heard about extracting energy from flooded coal mines.

Figure 10 indicated that energy related companies are most aware of the technology, however, more work is needed to educate the public and involve students in teaching and learning for long term adaptation of the technology. Also, more focus is needed to educate all groups regarding the principles of the technology and its benefits on the long term.

From the survey it was good to know that the majority of the companies involved in the energy and related sectors, and the policy makers (local councils) that take the crucial decisions regarding the matters related to the energy are aware of the technology. But, the survey also showed that the vast majority general public, that includes researchers, have very little information about the technology. It is therefore important that general public is made aware of mine water as an alternative energy resource, which is cost effective, environment friendly and easy availability. The companies and policy makers should engage and if possible show the technology in action to convince the general public.

5. Conclusion

It is clear from our workshop, LOCAL work packages and the on line survey that pathway to commercialisation could be considered for long term and short term aspect:

Short term: The technology could be feasible commercially for the short term if some conditions are available:

1. Infrastructure bore hole is available.

2. Water already pumped (for other reasons)

3. Government organisations can absorb the cost of infrastructure.

4. One main user of energy (e.g. hospital, university, shopping mole), where discussion and discussions can be simplified.

5. Water level is high (low energy for pumping).

The above conditions will allow shorter payback period and enhance the commercialisation process.

Long Term: On the long term, the following measures should be taken:

1. Integrate the technology with education and public media.

2. More public engagement programmes are needed.

3. Educate energy installers companies and provide training courses on how the technology works and how much it should cost.

4. Some legal issues should be resolved regarding the technology, particularly in relation to district heating.

5. The need to be able to change suppliers or ensure reasonable cost (cheaper than current technologies).