City-wide District Heat Network powered by Deep Geothermal in Stoke-on-Trent (UK)

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ABSTRACT

As any other European country, the United Kingdom faces the energy trilemma of cost, security of supply and carbon intensity of energy.

There are a limited number of city-wide district heat networks in the United Kingdom, i.e. less than 2% of market penetration; most are powered by natural gas combined heat and power plants or energy from waste plants. There are currently strong national drivers for decarbonising heat and the Department of Energy and Climate Change is supporting the development of district heat networks.

Stoke-on-Trent City Council is developing a city-wide deep geothermal district heat network, which is recognised as the largest low carbon heat network development in the UK.

There is only one small scale deep geothermal heat network in the UK, located on the south coast at Southampton, which was developed in the 1980s as a pilot and research project. The capital outlay required for such systems made them difficult to compete against cheap natural gas extracted in the North Sea.

Today the situation is changing, given North Sea natural gas is not as abundant and as economically viable to exploit, resulting in a large amount of natural gas being imported.

In a highly competitive liberal energy market, Stoke-on-Trent City Council is developing a Public Private Partnership scheme to enable a deep geothermal scheme to be delivered on a commercial basis in an environment where heat is yet to be regulated.

This paper will provide an overview of the mechanisms used by Stoke-on-Trent City Council to develop, and more importantly to de-risk such intensive upfront capital deep geothermal schemes.

1. INTRODUCTION

Following the oil crises in the 1970s, Scandinavian countries looked at efficient use of their imported fossil fuels, i.e. oil and natural gas and embraced Decentralised Energy systems in particular DHN (District Heat Networks). Today, the adoption of DHN in these countries exceeds 50% of the total market demand. Moreover, such countries are also using a high percentage of low carbon heat sources for their DHN, e.g. EfW (Energy from Waste), woody biomass, heat pumps, biogas produced by anaerobic digestion, and are on their way to zero carbon heating.

In the UK (United Kingdom), North Sea natural gas came into play in the 1970s avoiding to some degree drastic changes in the use of fossil fuels as seen in the North of Europe. Subsequently, a national gas distribution network was developed, and the grid today connects circa 80% of the population. Consequently, the UK has the largest market for gas boilers in Europe with around 1.6 million units installed or replaced in homes each year.

Figure 1 displays the primary energy use in the UK and almost half of such energy is consumed for heat.

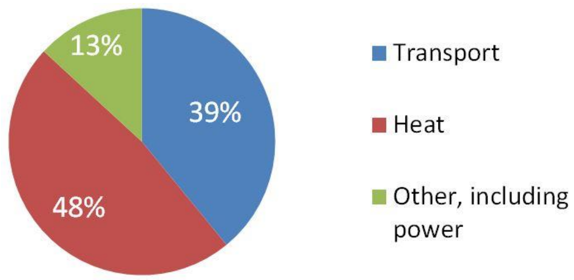

Figure 1: UK Primary Energy Usage for Heat, Transport, Other (DECC 2014).

Figure 2 shows the UK non-transport final energy consumption split by sector and end-use for 2013. Within the domestic sector 85% of energy was used for heating purposes. This is the biggest proportion from all three sectors for energy to be used on heating. The majority of heat use in the domestic and service sectors is for space heating, (77% and 72% respectively) whereas most heat consumption in the industrial sector was on heat processes.

Figure 3 shows that natural gas dominates space and water heating in 2013.

In 2009, around 32% of all GHG (Greenhouse Gas) emissions in the UK resulted from heat related activities as presented in Table 1.

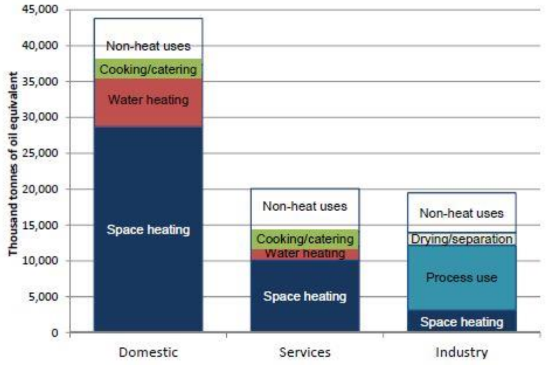

Figure 2: Non-transport final energy consumption by use by sector, DECC (2013).

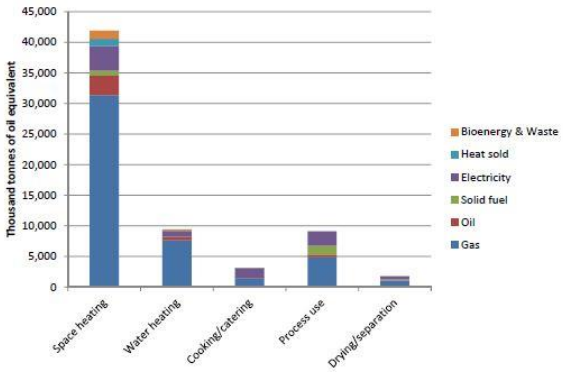

Figure 3: Non-transport final energy consumption of heat energy (DECC 2013).

Table 1: Proportion of total UK emissions related to heat (DECC 2009).

	CO_2 only	All GHG
Emissions from heat ($MtCO_2e$)	180	182
Total UK emissions ($MtCO_2e$)	474	562
Proportion from heat (%)	38	32

Like many other countries, the UK faces the energy trilemma, i.e. cost, security of supply and carbon intensity.

In 2015, nearly 38% of the gas used in the UK was imported. Therefore, the price of gas is volatile and most heating systems are using gas. All this evidence is leading to heat decarbonisation is part of the solution to tackle the energy trilemma.

DHN schemes do provide efficient gain and coupled with low carbon fuel, they can be part of the solution. This has been recognised by DECC (Department of Energy and Climate Change), and the strategy paper titled The Future of Heating, forecasts that DHN will grow to supply heat to buildings between 14% and 43% by 2050.

Today there is a limited number of city-wide DHN in the UK, i.e. approximately 2,000 schemes supplying 2% of buildings heat. Most of the schemes are powered by gas combined heat and power plants or energy from waste plants. DECC are currently supporting Local Authorities with the development of district heat networks.

Stoke-on-Trent City Council is developing a new city-wide low carbon DHN scheme involving potential deep geothermal hot sedimentary aquifer. The scheme is due to be released by 2019 and involves partnership with the private sector. This paper provides an overview of the project development.

2. DEMAND LED PROJECT

Low carbon DHN projects involve servicing a heat demand by a local heat supply source. It is paramount for financial and commercial reasons that the heat supply is located as near possible to the customers. This is to avoid costly heat losses and pumping requirements. Thus the art of delivering DHN schemes relies on optimising and balancing the supply and demand components and ensure they are both located in proximity.

This is even of bigger importance with capital intensive deep geothermal technologies and their inherent geological risks. The first step is therefore to map demand and supply.

2.1 Heat demand

Stoke-on-Tent City Council used the national heat demand published by DECC to start with a high level review of heat demand throughout the city. An energy masterplan was devised informing the strategy for the delivery of the DHN scheme.

The city of Stoke-on-Trent is made up of 6 towns that were unified in 1910 into a single unitary authority. Consequently, Stoke-on-Trent does not have a traditional city layout with a core city centre, but 6 separated town centres resulting in a long thin spread out city.

The total annual heat demand of the city was evaluated at circa 1,907GWh, and this included high intensive industry actors such as the renowned ceramic manufacturers using large amount of heat in their fabrication process, i.e. natural gas kilns.

Figure 4 shows the municipal boundary and the 6 towns; and the blue shaded zone represents the targeted area for phase1 of the DHN scheme with an annual heat load of circa 170GWh.

Focusing on this identified area, the larger heat consumers were identified. Their buildings and heat plants were surveyed, and their heat demand was calculated from actual utilities bills. This information was then compiled to define a contractible annual heat demand of above 48GWh.

Most of the potential customers for the DHN are using natural gas, but some use electrical heating systems. They would all benefit from a low carbon heat source, avoiding carbon taxation, avoiding cost to maintain existing systems as they would be redundant and ultimately using a stable and local renewable energy supply.

A minimum demand is required for the scheme to be financially feasible. To provide a “bankable” scheme it is important to de-risk the demand by trying to secure long term contracts to ensure sufficient revenue to service operation, tax, debt repayment and equity dividend. Such long term contracts are mainly entertained by public sector bodies.

The identified 48GWh annual heat demand is made up of almost 70% public sector actors, e.g. Council, University, large housing association.

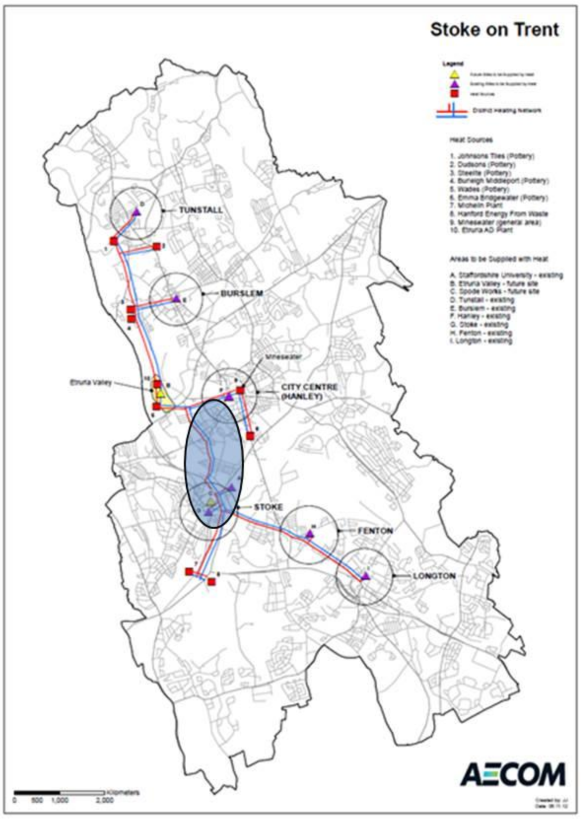

Figure 4: Stoke-on-Trent heat demand mapping.

2.2 Heat supply

Stoke-on-Trent City Council conducted a study in parallel to the heat demand to map potential low carbon heat sources. The work looked at minewater, woody biomass, EfW, heat pumps and deep geothermal.

Conscious of the energy trilemma, the Council was keen to use lowest carbon local source available and produced a commercial model to inform a techno-economic study of all the options.

Deep geothermal was retained as the first option for phase1 of the DHN.

The existing non CHP (Combined Heat and Power) EfW plant was also an attractive proposition however the plant is 45 years old and coming to its end of life in the next 4 years. This will also require a significant investment as well as contract and permit renewals. Therefore, it is anticipated that the new EfW facilities will be used for the expansion of the network phase2 and to serve a different part of the city to the blue zone identified in Figure 4. The EfW is also held as a backup solution in case of the deep geothermal solution failing to achieve the energy output required.

3. DHN COMPONENTS

DHN in the UK are not regulated and not considered as utilities. However, DHN schemes are often structured similarly to utilities, e.g. gas and electricity. Typically, the structure comprises three distinctive commercial blocks namely generation, distribution and supply.

These commercial entities can be discretely owned, or part of the same group. They can also be purely private or public sectors owned or a PPP (Public Private Partnership). Regardless of the ownership, it is paramount that the relationships and interactions are fully defined and agreed to ensure a successful commercial scheme.

These interdependencies are keys to the effective delivery of a DHN scheme and ultimately to the supply to the customers of the right service at the right price.

Stoke-on-Trent City Council is therefore developing the scheme with a whole system approach encompassing all three components. However, the Council cannot deliver the whole scheme financially and technically. The total investment required is estimated at £52.5 million as broken down in Table 2.

Table 2: Breakdown of the Stoke-on-Trent DHN scheme investment.

Investment	Cost in £ million	Investor
Scheme feasibility	0.5	Council
Geothermal well and energy centre	17	Private Sector
Scheme delivery	3.9	Council
Network infrastructure	19.8	Council
Supply	11.3	Private/Public?
Total	52.5	

Stoke-on-Trent City Council is able to finance and deliver the heat network infrastructure following the receipt of a central government grant. This grant was accessed by demonstrating a market failure whereby no investors were able to invest in the network infrastructure despite actors coming forward for the generation and supply components. This is due to the limited returns that can be made on high capital costs of heat network infrastructure. This is not surprising as for this very reason, existing energy and transport infrastructure projects were mostly funded by tax payer money.

The deep geothermal doublet system and its energy centre will be delivered by the private sector.

The Council is currently assessing various options for the delivery of the SPV (Special Purpose Vehicle) for the supply component.

Figure 5 show the potential commercial structure for the whole scheme.

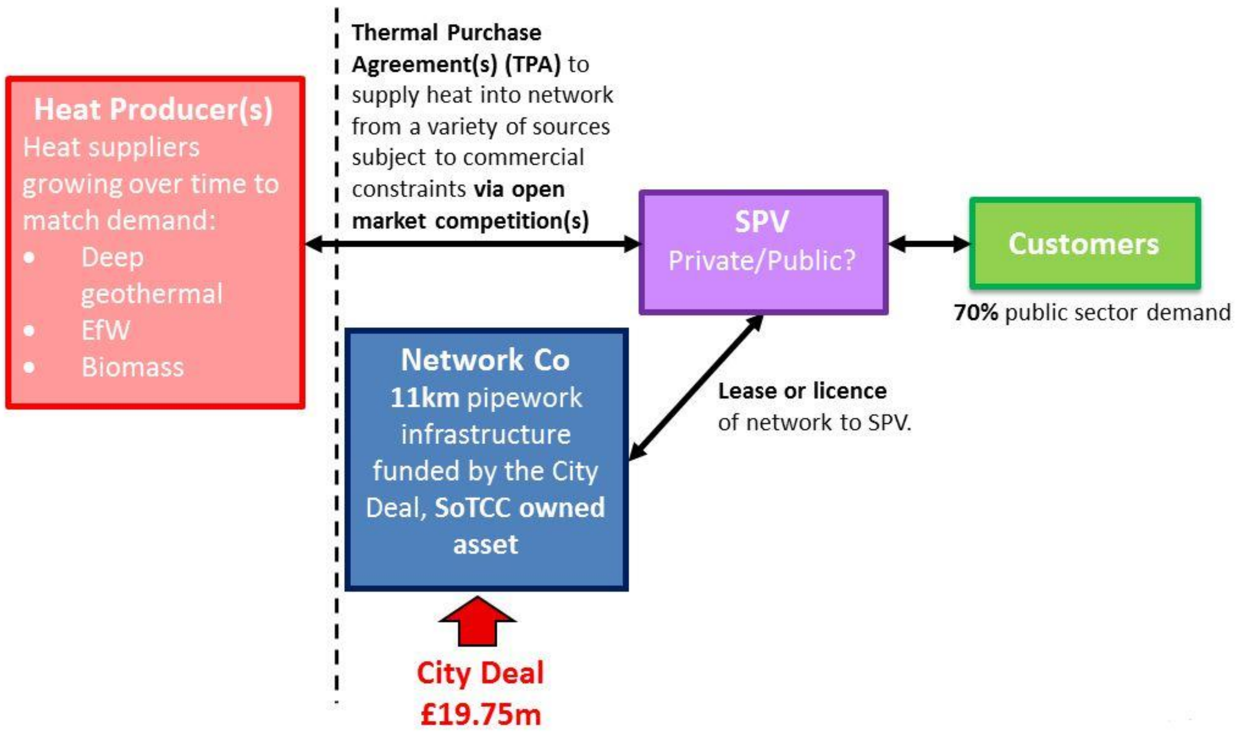

Figure 5: Potential Stoke-on-Trent DHN scheme structure.

4. ROLE OF STOKE-ON-TRENT CITY COUNCIL

4.1 Customer

As mentioned in Chapter 2.1, Stoke-on-Trent is committed to enter a long term heat purchase agreement to de-risk the DHN scheme. Obviously public procurement regulations have to be followed, and therefore the heat price has to be competitive. This provides a win-win solution for both the Council itself and also the SPV.

The Council would therefore act as a key customer enabling the scheme to gain critical mass to provide “bankability”.

Furthermore, the Council can facilitate dialogue with other public sectors bodies, e.g. universities, colleges, schools, hospitals, housing associations, care homes and more, with a view to generate further long term contractible heat demand resulting in the risk profile for the project being significantly reduced.

Subsequently, there is significant potential to provide sustainable and stable priced heat to commercial and domestic users over the medium to long term and to create key benefits for the growth of the DHN scheme.

4.2 Distribution

With the advantage of the secured capital grant of £19.75 million, the Council will deliver the Network component of the DHN scheme.

The network may, amongst other options, be leased or licenced to the SPV to transmit the heat between heat producer and customers.

The SPV will therefore be involved in the design of the network to ensure the infrastructure is fit for purpose but with the infrastructure remaining in the Council’s ownership in perpetuity.

The heat network is clearly the backbone and therefore critical to the whole DHN scheme delivery. The Council is therefore playing a key enabler role.

4.3 Generation

Deep geothermal developers are likely to release capital investment only if a TPA (Thermal Purchase Agreement) is in place with an SPV to purchase a pre-defined amount of heat energy to ensure they can raise the finance to execute the first exploration drill. There is no UK government backed risk insurance for geothermal exploration drills.

The role of the Council is to provide a platform between the SPV and the potential heat producer to engage into the TPA negotiations.

The Council, as a planning authority, has commissioned various feasibility studies to understand the potentials of deep geothermal as a heat source but to also understand the technology overall.

This is critical due to the strong opposition to the extraction of shale gas in the UK, in particular against the stimulation technology employed. The term "drilling" has become very emotive and in many cases people are not equipped to fully understand the technology. This could lead to deep geothermal projects being assimilated to gas extraction projects, therefore receiving negative responses.

It was important for the Council to have all the information beforehand to make an informed judgment and to then promote deep geothermal energy as safe to its citizens and businesses to ensure a good delivery of the scheme.

The Council commissioned studies to look at sources of exiting geology and geophysical data, such as seismic reflection data acquired in 1980s, borehole data, coal authority data and mine workings temperature records. Furthermore, 90km of 2D seismic reflection lines were reprocessed. The conclusion from all this data was the potential location of a hot sedimentary aquifer around 95°C located in lower carboniferous limestone at a depth of 2.8km.

Figure 6 shows a map with various sources of data, and the yellow lines depict the conceptual traces for two new 10km seismic line required to ascertain the geology locally to the potential drill site.

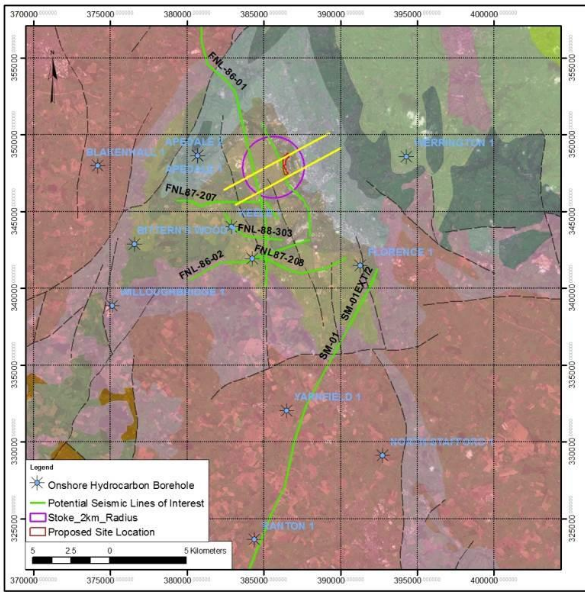

Figure 6: Existing geology and geophysical data.

The Council has since commissioned the new 20km 2D seismic acquisition survey that took place in early 2016. A total of 9 months was used to design, plan and permit the survey. The fact that the municipality was the actual recipient of the survey meant that discussion with all public consultees was greatly facilitated. Needless to say, a large public campaign was driven by the Council to ensure that citizens and businesses understood why a seismic reflection survey acquisition was required. This was also very beneficial to demystify deep geothermal and DHN.

The survey campaign was completed within 9 days in a challenging urban environment as shown in Figure 7.

The interpretation of the new data will provide greater understanding and mapping of the reservoir to target, and all potential implications. The work is due to complete during summer 2016.

Figure 7: Photos of the recent seismic acquisition campaign.

4.4 Supply

The SPV will purchase heat from the generator through a TPA via open market competition and will sell this heat to consumers as shown on Figure 5.

To de-risk the proposition to the SPV, the Council has carried out an extensive heat demand profiling with potential public and private large heat users, as explained in Chapter 2.1.

It is clear that the SPV carries many risks, but given that Stoke-on-Trent City Council have mapped and provided mitigations for most of these, it would be natural for the Council to participate in the SPV and recoup some of its investment.

Therefore, the Council is looking at options for the delivery of the SPV for the supply component. These are 100% owned by the private sector, JV (Joint Venture) and 100% owned by the Council.

A soft market testing exercise was conducted early 2016 and Figure 8 depicts a high level appraisal according to the responses received from the market for the three SPV options.

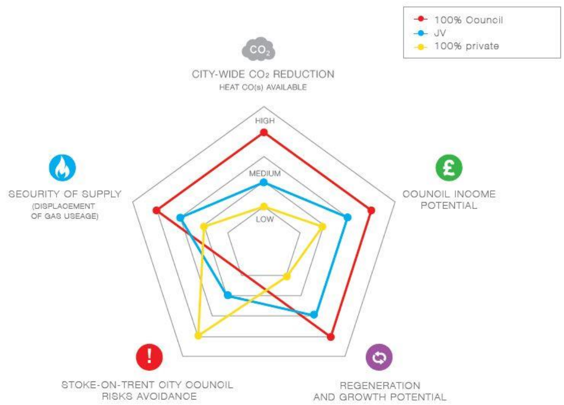

Figure 8: Risks and rewards diagram, appraisal of SPV ownership benefits for Stoke-on-Trent City Council.

The commercial model is being revised to understand the level of investment required versus the potential expected revenues - in other words the analysis of risks and rewards. The Council will make a final decision about the structure of the SPV in the autumn of 2016.

5. CONCLUSION

Deep geothermal DHN schemes are complex due to the multiple interconnected components, all required to collaborate and cooperate with each other.

A whole system approach is therefore paramount to develop and deliver successfully such a project, and components cannot be singled out and dealt with in isolation.

And as for any Business, the most important consideration is the customer. It can take some time to explain and sell the benefit of technology that is perceived to be innovative - despite being widely implemented in other EU countries.

It is also really important to develop a sustainable system, i.e. providing balance between economic, environment and social factors. Schemes have to be financially and commercially viable and they should not depend on long term subsidies to succeed.

Therefore a lot of resilience, continuity, perseverance and flexibility are required to allow the blocks to fit into place and to fit each other perfectly. This is why local authorities and municipalities are best suited to lead in the development of these types of projects and to do so in partnership with the private sector for implementation.

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