Decentralised Energy Development: A study examining its potential to drive economic regeneration in the UK

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Abstract

Following the 2008 financial crash the UK Government, through the Local Enterprise Partnership model has been driving major economic regeneration in localised economies for high value job creation, uplifting skills and infrastructure investment. LEPs are the prime vehicles to identify and deliver their own programmes to gain increased economic growth through targeted and localised support.

The Stoke-on-Trent and Staffordshire LEP having a below average performing business base, developed a unique "Powerhouse Central" proposal for its regeneration funding submission into Whitehall. The proposals centred on delivering decentralised energy infrastructure in the form of Stoke-on-Trent district heat network (DHN), and the Keele University Smart Energy Network Demonstrator (SEND). The DHN and SEND are complementary projects, the DHN utilising off the shelf technology to de-risk the project and encourage private investment models to be applied to UK DHN pipeline projects, whilst the Keele SEND allows dynamic smart network technologies to be tested and trialled, both from the hardware and software perspective but also from the social interaction dimension in an idealised small town sized community.

Decentralised energy using localised energy resource assets give increased levels of supply security to business, public services and residential populations something that is becoming more difficult with the existing large-scale generation system. The DHN and the SEND gives the opportunity for localised supply chain diversification providing a key element of the LEP's economic regeneration commitments; this observational study has researched and examined drivers, conflicts and barriers to deploying the DHN and SEND projects specifically regarding the deployment of business support strategies and programmes to drive supply chain diversification and innovation into the decentralised energy opportunity. It is apparent that technology and finance are not the key barriers to decentralised energy supply chain growth but relate to the conflict and non-aligned politics pursing national and local agendas.

Acknowledgements

I wish to offer my sincere thanks to Dr Sharon George for her inspiration and guidance throughout this project especially through the difficult times, when combining the study with running an engineering business was a difficult balance.

I wish to express my gratitude to my wife Sandra and my children Beth and Sam for their support and patience over the last few years.

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AD	Anaerobic Digestion
ADBA	Anaerobic Digestion and Biogas Association
AMM	Abandoned Mine Methane
AMRICC	Advanced Material Research, Innovation and Commercialisation Centre
bCHP	Biomass Combined Heat and Power
BAT	Best Acceptable Techniques
BEIS	Dept. of Business, Energy and Industrial Strategy
BGS	British Geological Society
BIS	Dept. of Business, Innovation and Skills
CBM	Coal Bed Methane
CCA	Climate Change Agreement
CCL	Climate Change Levy
CER	Certified Emissions Reduction (Unit)
CHP	Combined Heat and Power
CMM	Coal Mine Methane
CRC	Carbon Reduction Commitment
CVn	Calorific Value nett
DCLG	Department of Communities and Local Government
DE	Decentralised Energy
DECC	Dept. of Energy and Climate Change
DEFRA	Dept. of Environment, Food and Rural Affairs
DEPA	District Energy Procurement Agency
DHN	District Heat Network
DUKES	Digest of UK Energy Statistics
EA	Environment Agency
ECO	Energy Company Obligations
EfW	Energy from Waste
ERDF	European Regional Development Fund
ESCO	Energy Supply Company
ESIF	European Structural and Investment Fund
EU ETS	European Union Emissions Trading Scheme
EUA	European Union Allowance
FIT	Feed in Tariff
GE	General Electric
GHG	Greenhouse Gas
GIS	Geographic Information System
GMCA	Greater Manchester Combined Authority
GVA	Gross Value Add
HNDU	Heat Network Development Unit
IPPR	Institute for Public Policy Research
IRR	Internal Rate of Return
ISTM	Institute of Science Technology and Medicine
JLR	Jaguar Land Rover
LA	Local Authority

LCIDG	Low Carbon Industrial Development Group
LEP	Local Enterprise Partnership
MDG	Mine Drainage Gas
NAP	National Allocation Plan
NCB	National Coal Board
OGA	Oil and Gas Authority
PEDL	Petroleum Exploitation and Development License
PFI	Public Finance Initiative
PV	Photovoltaics
RDA	Regional Development Agency
REA	Renewable Energy Association
ROI	Return on Investment
SCC	Staffordshire County Council
SEND	Smart Energy Network Demonstrator (Keele University)
SOTCC	Stoke-on-Trent City Council
SRC	Short Rotation Coppice
SSLEP	Stoke-on-Trent and Staffordshire Local Enterprise Partnership
STEM	Science Technical Engineering & Maths
tpa	Tonnes per annum
UKCCC	United Kingdom Committee on Climate Change
UNFCCC	United Nations Framework Convention on Climate Change
USP	Unique Selling Point
WET	Waste and Emissions Act
WID	Waste Incineration Directive

1. Introduction

1.1 – Objectives

This study has researched and considered, by observation through the Local Enterprise Partnership public and private engagement model within the Stoke-on-Trent and Staffordshire LEP, the opportunity for “Decentralised Energy” generation as a localised energy resource and outlined the interplay with supporting regional economic regeneration. The “Decentralised Energy” technologies to be considered will range from mine gas through mine water geothermal to biogas and syngas generation from localised feedstocks.

Therefore, the key relevant questions to be considered from these statements and observations which are pertinent to this research are:

- How to transform the UK Heat Supply market?
- How to drive supply chain growth into this transformed Heat Supply market?

The study has focused on synergistic deployment to meet and satisfy specific power demands from residential and commercial activity in an urban situation. The potential for interlinked energy generation and security that could be available in these post-industrial areas utilising Coal derived methane (mine gas – Coal Bed Methane), geothermal power from mine water recovered systems, to localised energy relating to waste industrial heat will be researched with a view to its suitability for deployment into a localised energy solution. This will require analysis and observation of several area incorporating:

- An overview of the present-day deployment state of the CBM, Geothermal, District Heat and Smart network technologies - *as applied into the Stoke-on-Trent DHN and the Keele University SEND project*;
- A comparison of regional economic regeneration strategies for aims and policies – *support programmes*;
- A discussion of the basis for economic and regulatory frameworks that need to be interlinked to

support and drive "Decentralised Energy" technology deployment – *as per the Heat Network Development Unit (HNDU) programme*;

- The development of potential future energy technology opportunities to be linked into Carbon mitigation solutions such UCG, CCS etc. – in terms of additional energy potential from "Cleaner" Fossil fuel use – *example of the Goodwin International involvement in the Allam Cycle Turbine project*.

These areas need to be interlinked with a coherent approach from central and local Government, business support programmes delivered by public or contracted bodies. The research will identify these interlinks and relevant stakeholder groups.

The integration of the Departments of DECC and BIS together to form a new Department of BEIS – Business Energy and Industrial Strategy, by the new Prime Minister in 2016, is an indication that the "new" UK Government has seen a fundamental strategic link between having a modernised and secure Energy generation and supply system; as a way to drive and underpin a new strategy for Industrial growth. But, whilst being aware of this shift in policy the study timeline will not be able to analyse in depth as resulting policies and programmes are not (as of March 2017) in place.

Key objectives were researched to decipher which appropriate policy drivers can be utilised to work in specific sector areas such as:

- hardware and software business enterprise developments,
- social networks for communication routes to business and public audiences to gain decentralised energy buy-in to support deployment,
- to transform financial market behaviour to build models to alleviate traditional risk aversion levels.

This will then lead to a view on the type of support programmes and mechanisms which should be designed and deployed to actively support economic regeneration opportunities, aligned with decentralised energy.

1.2 – Background to research

Numerous challenges face the UK and the wider EU regarding meeting legally binding greenhouse gas emission reduction targets as required under EU commitments, under the Kyoto Protocol 2005-2012 and then under the extension of the Doha Amendment 2012 onwards. This is combined with a transfer to a low carbon-based economy, driven by the legal requirements of the EU Directive 2009/28/EC for the promotion of the generation of energy from renewable low carbon sources.

Following the financial downturn of 2008, the Coalition Government (2010-2015) and the Conservative Government of (2015 to 2016) set a focus for the UK economy to be restructured; from a service-led economy to one with a greater part played by manufacturing and industry reversing a forty-year downward trend (Treasury Office, 2013). In order to achieve this, Theresa May restructured Government Departments and brought the activities of DECC, the Department of Energy and Climate Change, and that of BIS the Department of Business Innovation and Skills together to form a new Department of Energy and Industrial Strategy, BEIS.

BEIS is the department that brings together responsibilities for business, industrial strategy, science, innovation, energy and climate change. The BEIS website at URL: https://www.gov.uk/government/organisations/department-for-business-energy-and-industrial-strategy/about as of September 2016, gives specific detail on the range of tasks the department is assigned with, including:

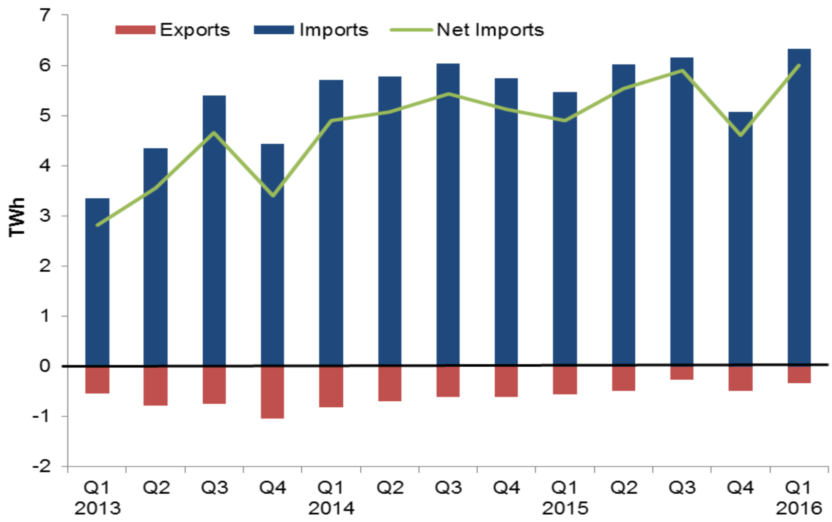
- Developing and delivering a comprehensive industrial strategy and leading the government's relationship with business
- Ensuring that the country has secure energy supplies that are reliable, affordable and clean
- Ensuring the UK remains at the leading edge of science, research, and innovation
- Tackling climate change

The brief of the new department was to focus on integrating energy developments as a key part of the re-energising of the manufacturing and industrial sectors started in 2010.

The UK's infrastructure base has been in decline since the early 1970s (Treasury Office, 2013). This decline is seen physically throughout the Midlands, North, and Scotland with large tracts of the urban landscape being in a redundant state. For these regions, it is an ongoing challenge and there is a need to drive investment in infrastructure to kick start and keep economic regeneration moving forward.

Within the Midlands area, the region of Staffordshire and Stoke-on-Trent has particularly been subject to this post-war decline, seeing its traditional industry mix of steel, coal, and ceramics all winding down at the same time; with the linked job losses and subsequent lowering of economic performance and expectation over the period of the 1980's and 1990's (Stoke-on-Trent & Staffordshire City Deal, 2014). City Deal: Stoke-on-Trent and Staffordshire. Retrieved from URL https://www.gov.uk/government/publications/city-deal-stoke-on-trent-and-staffordshire).

DECC in DUKES data in 2015 (Digest of UK Energy Statistics, 2015) was reporting that the UK was moving from being a net producer of natural gas, from its offshore gas reserves, to a net importer position with a corresponding move from being a net exporter of generated electrical power to a net importer. Subsequently, the issue of energy security figures very strongly from central government down to the atypical manufacturing SME boardroom. The situation of electrical generation, as shown in Figure 1 and 2, is particularly of concern as it highlights an area of potential weakness of the overall UK power mix. It is evident that we have strategically moved from a level of installed capacity to be able to "sell" (export) electrical power through the various interconnectors in place between the UK to Ireland, France and the Netherlands, to a position today that sees an increasing need to import electrical power just to keep the national grid operating at periods of peak demand.



UK Electrical Generation Balance Imports vs. Export

Figure 1: UK Electrical Generation Balance 2013-2016 (DECC DUKES Q2, 2016)

The situation as outlined by UK Government's own figures, as shown by DECC and in DUKES (Digest of UK Energy Statistics, 2015); showing the UK grid supported electrical generation that continued to fall from 371 TWh in 2004 to 335 TWh in 2014. In June 2013 OFGEM, the generation industry regulator, warned that the UK faced "unprecedented challenges" and that spare electricity power production capacity would fall to 2% by 2015, "increasing the risk of blackouts". OFGEM postulated that solutions to alleviate this knife edge situation could range from negotiating with major power users to reduce demand during peak demand times, to mothballing aging coal, oil, and gas plants in an operational condition to be brought into use to boost supply at predicted peak demand (OFGEM State of Capacity Report, 2013). This view of a knife edge is based on an installed capacity of what is officially perceived as being at a critical point with little to no margin if an unexpected power station outage occurred during a winter peak period. The margin is now down to below 2% of predicted peak demand winter period (Digest of UK Energy Statistics Q2, 2015).

Politically, Government has stated it will not let a blackout or brownout situation occur. In reality the UK Government has plans set out through DECC, BIS, The Treasury, and also the Cabinet Office, to ensure that residential and public services such as hospitals are not "cut-off"; such that businesses are vulnerable to being cut off in preference to the voting public. Therefore, businesses will be taken out of the Grid and will be effectively “shut down” unless they have their own generating hardware assets in place to cover the outage. The power of the “outage” threat leading to businesses after the snowstorms in November-December 2010, when the power suppliers issued “outages” to industry led the ceramic businesses: Dudson, Steelite, Johnson International and others to lobby into Local and National Government that they needed assured energy supplies. This was due to their manufacturing processes not being able to handle unplanned short notification, and the fact that they would be essentially bankrupted by any “outages”. With the ensuing large levels of local unemployment caused, this was presented as one of the initial drivers for the establishment of the Low Carbon Industrial Development Group (LCIDG) to look for possible solutions towards gaining energy security, by Sebastien Danneels the DHN Technical Lead at Stoke-on-Trent City Council at the DEPA launch event in late 2016 held in Manchester.

The Stoke and Staffordshire LEP has experienced a lack of technical knowledge by DECC in 2012 in meetings on its City Deal proposals regarding the present state of the UK ceramic industry related to the risk of commercial shutdown, with no ability to restart due to industry aimed energy “outages”. The research author, as a LEP Board Director from 2012 to 2016 has had a personal experience by observation and in discussions with senior DECC officials in that they had a total lack of understanding of the commercial and operational implications.

Therefore, for the Gross Value Added (GVA) component of the UK economy, including industry, the private service and retail sectors there is an emerging period of energy insecurity (DECC UK Power Generation Infrastructure Review, 2011) both of supply and generation. This situation makes it difficult for energy consuming businesses to financially figure in energy supply instability effects into planning and investment cycles, other than investing in power generation assets or finding a localised power generation service that gives security and essentially an off-grid solution.

An example is the tile manufacturer Johnson International's sister company, Norcross, taking on the Petroleum Exploitation and Development License (PEDL) rights (DECC 14th Onshore PEDL Round, 2015) to develop Coal Bed Methane (CBM) extraction in the Etruria Valley in the centre of Stoke-on-Trent. This development by Norcross would bring coal-related gas use back into the ceramic industry as a strategically "safer" fuel away from National Grid supply. This creation of a "local" base for power generation is becoming a key policy of Central Government. Government, due to its political posture of allowing the market to lead in investment decisions in the 2000s and 2010s, is showing no indication of finance or political will to invest in a nationalised power generation capacity, as it did in the 1960s and 1970s when the power generation and grid infrastructure where in public ownership and thus subject to new build investment to replace obsolete plant.

The problem is that this nationalised industry-produced capacity is now at, and beyond, its operational design life of 40 years and needs to be replaced (DECC UK Power Generation Infrastructure Review, 2011). This DECC review of power generation infrastructure shows that effectively the UK is now some 20 years late in starting to replace its national grid based power generating capacity; as part of a wider encompassing infrastructure replacement programme covering not just energy but also roads, schools, rail, affordable housing. Therefore, other than injecting vast amounts of public finance, which it is politically and financially unable to do as this would go against the 2010 Conservative party ethos to support market driven forces, Government must consider support programmes to stimulate and support a balance of private investment.

This national investment need is outlined in the Treasury paper "Investing in Britain's future of 2013", developed by the Coalition Government then in power (Treasury Office, 2013). Figure 2 shows UK Electrical Generation Capacity Loss due to Planned Closure.

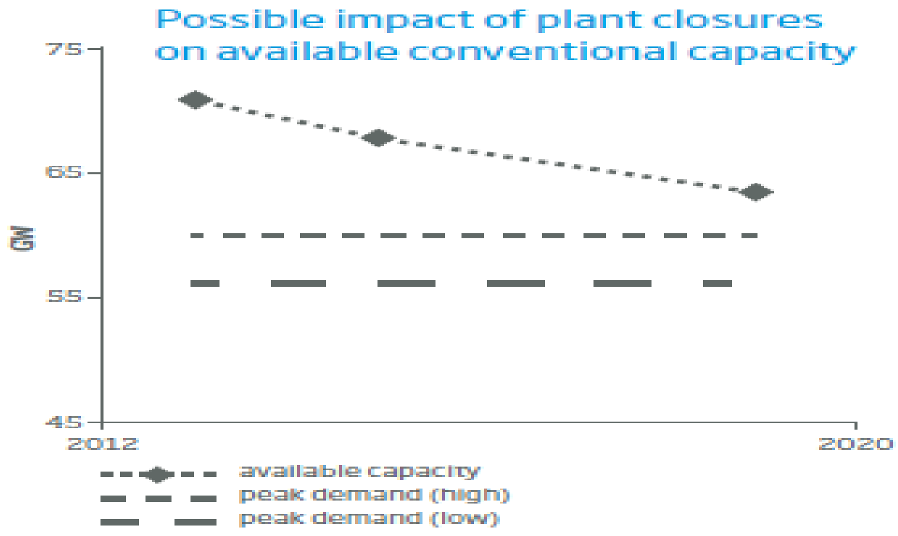


Figure 2: DECC UK Power Generation Infrastructure Review 2011

In December 2011, the UK Government set out its Carbon Plan with the following statement:

> *"The 2011 Carbon Plan set out that if the UK is to play its part in the global effort to combat climate change, we will need our buildings to be virtually zero carbon by 2050. Achieving this can help our exposure to the kind of volatile fossil fuel prices which led to a 9.4% rise in average prices last year (2010), driven overwhelmingly by the wholesale gas price on global markets" (UK Carbon Plan, 2011).*

In the intervening period from the setting of the Carbon Plan to today we have seen a significant reduction in oil and gas prices. The old Department for Energy and Climate Change (DECC) and now the Department for Business Energy and Industrial Strategy (BEIS) have indicated in the 2016 Q1 DUKES publication (Digest of UK Energy Statistics) that this a transitory market effect with the long-term view is fossil fuel prices will rise and this should be the driver for Government Policy.

When considering options to the UK Government other drivers are seen to come into play, due to carbon reduction commitments, which are a legalised requirement; Kyoto, Copenhagen and now Paris as COP21. In the early 2000's the UK also introduced a subsidy system to promote private take-up of low carbon and renewable electrical generation. These are known as the Feed in Tariffs (FITs) for small scale generation and Renewable Obligation Certificates, ROCs for larger scale MW based generation. The overall aim of these measures was to reduce the GHG, Greenhouse Gas footprint associated with generating electrical power. It can be seen in Figure 3 that the UK has three main components to its GHG footprint with emissions relating to electrical generation, transportation and heat generation.

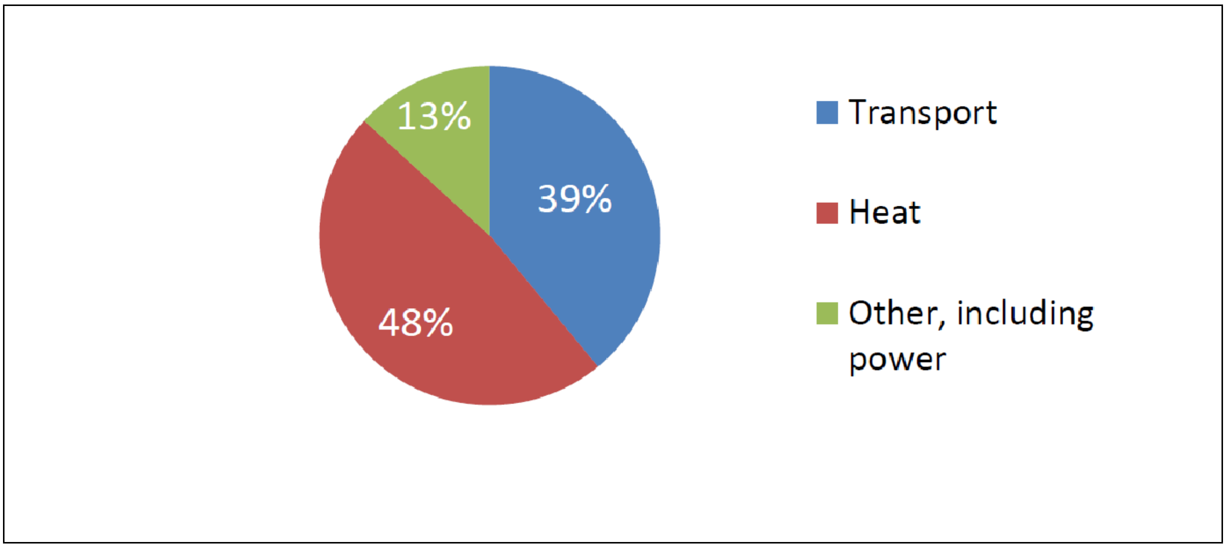


Figure 3: UK GHG Emissions Sectorial Split (DECC Heat Strategy, 2012)

Government policy is approaching these sectors in differing ways. For electrical generation, which has the smallest GHG footprint, as of 2012 the FIT subsidy levels have been markedly reduced with an eventual target to have a zero FIT level for solar and onshore wind in the next 4-5 years.

This is because from a governmental perspective the FITs have achieved a reduction in GHG in relation to electrical power generation so now normal market forces will be allowed to take over (The Carbon Plan, 2011). The installed cost of solar PV has indeed seen a dramatic fall in hardware cost as the demand has risen (Barron, 2015) and the manufacturing supply base has grown in capacity; particularly in China which has the highest level of PV take-up (Parkes, 2015). Therefore, in the UK, the Government sees the solar market as established, so the FIT for solar has been reduced to a low level.

Transportation policy to reduce GHG related emissions is identified as an infrastructure investment area (Treasury Office, 2013) and are configured around two main axioms:

- Infrastructure build up for increased usage of electrical powered vehicles.
- Reliance on European regulation around ever improving energy efficiency and emissions standards for fossil fuel powered vehicles, with the EU now currently moving to EU Cat6 standard.

In the period of the Coalition Government of 2010 to 2015 the UK Government was not as radical as the German Federal Council (Bundesrat) in its target to eliminate the manufacture of fossil powered cars by the combustion engine by 2030.

The largest source of CO_2 emissions is heat, as shown in Figure 3, accounting in 2014 for 48% of the UK GHG emissions. As shown in the DECC 2012 Heat Strategy paper this area is now subject to focused government policy, as the UK Government judges that the electrical generation sector emissions are now under control and in a reducing mode.

Hence the move onto the more complex heat sector, this sector has a number of facets, heat generation for space heating of homes, offices, industry, public buildings and also for use in manufacturing as thermal processing such as in the steel industry, ceramics as large heat users down to small heat users as in micro industry, e.g., microbreweries who generate heat needed in their brewing process.

The DECC 2012 Heat Strategy specifically has the level of heat, in terms of efficiency and reduction use in buildings, as the principal target in the present UK focus for Energy policy and Decentralised Energy development (DECC UK Heat Strategy, 2012). It is accepted that for the next 50 years the building stock we currently have predates the last 20 years focus on thermal efficiency; therefore, new build solutions, to the problem of building thermally efficient homes, are needed as it will only represent around a maximum of 20% of the built environment by 2060 onwards.

Therefore, effort and policy is to be directed at making what already exists more efficient with better insulation and the integration of Smart metering, linked with where practical deployable micro technologies such as heat pumps solar thermal heating for water. The main area of focus though is to greatly increase the use of decentralised energy (DE), as in District Heat Networks, DHNs in the UK. The 2012 Heat Strategy in its Executive Summary – "The Heat Challenge" opens with key statements that are seen as drivers towards Decentralised Energy. These are key to this piece of research and are shown in Figure 4 for clarity and context setting:

- *Heat is the single biggest reason we use energy in our society. We use more energy for heating than for transport or the generation of electricity. This year the UK will spend around £33 billion on heat across our economy.*
- *We use heat to keep our homes and offices warm, and we use energy to cool them in hot weather. We also use heat to provide us with hot water, cook our food, and manufacture the goods such as steel, iron, cement and chemicals, upon which our economy depends.*
- *Today the vast majority of our heat is produced by burning fossil fuels (around 80% from gas alone), and as a result heat is responsible for around a third of the UK's greenhouse gas emissions.*
- *This is unsustainable. The 2011 Carbon Plan[1] set out that if the UK is to play its part in the global effort to combat climate change, we will need our buildings to be virtually zero carbon by 2050. Achieving this can help reduce our exposure to the kind of volatile fossil fuel prices which led to a 9.4% rise in average gas prices last year, driven overwhelmingly by the wholesale gas price on global markets.*
- *The transformation of heat-generation and heat-use will create new markets and new opportunities. The EU market for heat pumps alone was responsible for three-quarters of million units sold last year,[2] and there is a chance for the UK to capture more of this market as we make the change to low carbon heat. This will be a national transformation, and also a local one, with different solutions for different localities and geographies as households, businesses and local authorities choose the approach that will work best for them.*
- *This document sets out how we supply and use heat today and describes how the heat system will need to evolve over time, identifying the substantial changes required across our economy and the role for government.*

1. Available at http/www.decc.gov.uk/en/content/cms/tackling/carbon_plan/carbon_plan.aspx
2. European Heat Pump Association Outlook, European heat pump statistics

Figure 4: The Heat Challenge – UK Heat Strategy 2012 Executive Summary (Source: DECC 2012 Heat Strategy, Page 4)

The highlighted fifth statement in the Executive Summary of the DECC 2012 Heat Strategy is very important to the policy and drivers for developing Decentralised Energy as it emphasis how the transformation of heat generation, delivery, and end use will create new markets.

This creates supply chain growth and diversification opportunities for existing companies and new start-ups. This is also shown in the first statement in the 2012 Heat Strategy Executive Summary it is viewed that as the production and delivery of heat is a £33 Billion pa market in the UK is a key part of obtaining the right setting for Economic Regeneration to occur.

The 2012 UK Government Heat Strategy document, "The Future of Heating: A strategic framework for low carbon heat in the UK" (UK Heat Strategy, 2012, p. 210) aims to start a revolutionary move to DHN take-up. Financial support has been provided to enable any England or Wales Local Authority (Scotland has its own policy developments underway) to undertake initial opportunity and baseline feasibility studies for DHN systems. The DECC Heat Strategy identifies key areas why heat usage is taken as a priority for change over electrical generation drivers, the report shows how overall UK energy consumption in 2009 was driven by Heat demand as in Figure 5 "Energy Consumption for heat by Sector";

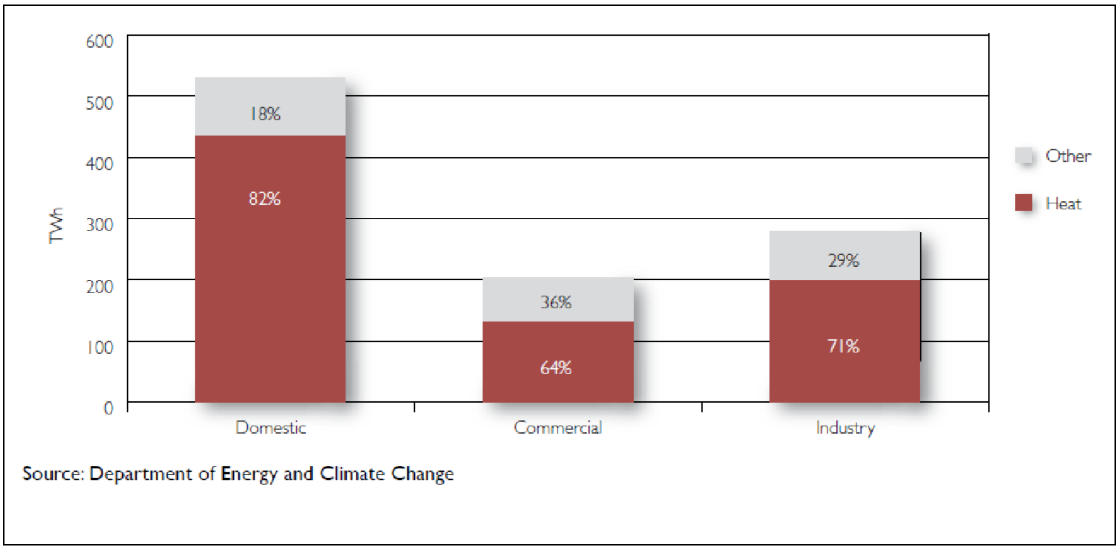


Figure 5: Energy Consumption for heat by Sector (DECC, 2009)

This view on Energy consumption under further analysis in the DECC Heat Strategy identifies quite clearly that space heating is the key area of usage across the three prime sectors of Domestic/Residential, Commercial, and Industry as shown in Figure 6: "Energy consumption for heat by sub sector and end use".

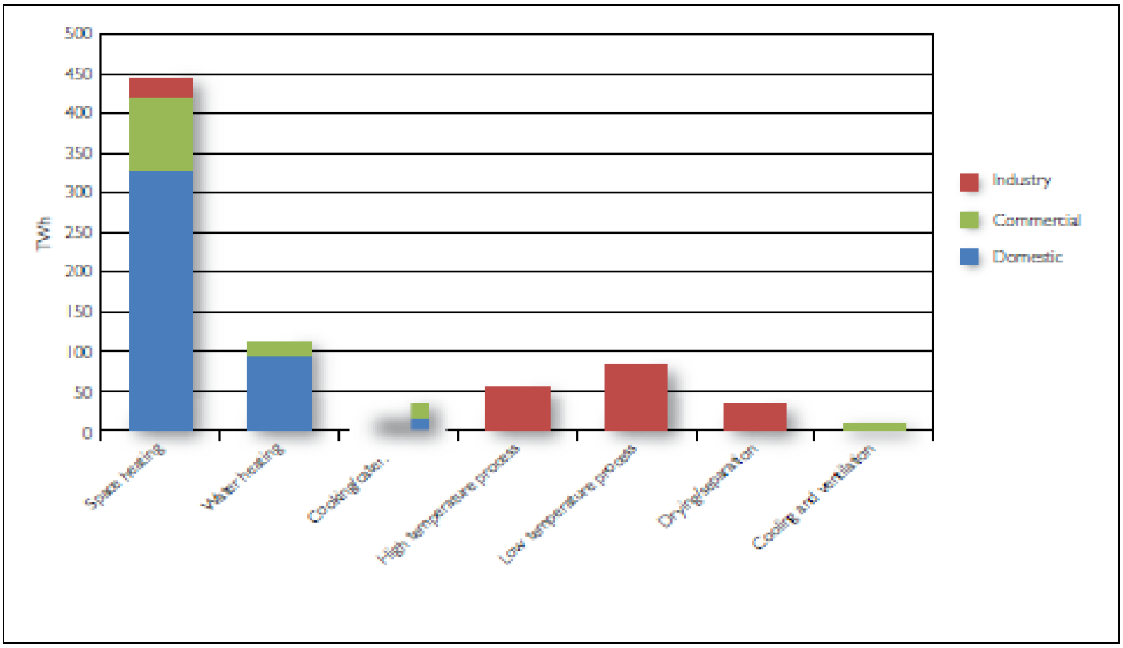


Figure 6: Energy consumption for Heating by sub sector (DECC Heat Strategy, 2012)

According to the DECC 2012 Heat Strategy documents, the UK has less than 2% of its heating supplied in Heat Network systems.

There are number of themes within the 2012 Heat Strategy on reducing the demand for heat generation and meeting Carbon Budget legal targets, as set out in the Government Carbon Plan of 2011 (DECC, 2011).

This led, by late 2015, for DECC/BEIS to have a specific listing of over 100 projects (listing given in Appendix I) for District Heat Network (DHN) development ranging from small few hundred metre systems to multi km systems as-such as the Stoke-on-Trent DHN project which in Phase 1 comprises a 17 km (depending on final routing) spine network infrastructure with an operating heat demand of 48GWh (Stoke-on-Trent and Staffordshire LEP Annual Report, 2015).

To this end, many industrial and service businesses must figure into their location strategy the issue of competitive and secure energy supplies; combined with the needs of Local Authority economic regeneration plans there is an opportunity for a number of historic urban industrial areas to consider the energy potential arising from their industrial past.

2. Literature Review

2.1 - Economic Regeneration – Barriers & Drivers for LEPs

Economic regeneration is a process that is widely experienced across both towns and cities; whereby the need to adapt and respond to both challenges and opportunities presented to urban environments is apparent (Roberts et al, 2000). Roberts et al (2000) define this process as a "comprehensive and integrated vision and action which leads to the resolution of urban problems and which seeks to bring about lasting improvement in the economic, physical, social and environmental condition of an area that has been subject to change" (Roberts et al, 2000, p.17). The regeneration of spaces ensures that "urban areas make a positive contribution to national economic performance" (Roberts et al, 2000, p.19), and subsequently benefit society. Urban regeneration has increasingly involved numerous stakeholders including public and private sectors working together to achieve the same priorities (Roberts et al, 2000). The importance of good communication, and in particular a common terminology, among bridging organisations working across regeneration projects has been highlighted (Kampelmann et al. 2016). Local Enterprise Partnerships (LEPs) are one of key manifestations of the private and public sector working together in partnership following their creation by the UK Government in 2010, with the aim to bring together stakeholders in the local area (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014). This development in government policy saw the creation of 39 LEPs across England (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014), all of which operate at a sub-regional scale whilst following central government policies and objectives for economic growth and prosperity within the country.

Doyle (2013) states that LEPs are "arrangements between local authorities and businesses, operating at the local level, intended to determine local economic priorities and strategies" (Doyle, 2013, p.2), and this private-public partnership is based around "local expertise and experience to help local growth, and bring future prosperity" (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p.2) to LEP areas. They have priorities focused on bringing power to local communities and business partners, as well as "tackling barriers to growth and supporting investment" (Mellows-Facer, 2011, p.5), LEPs can drive development by bidding for capital from funds such as the Regional Growth Fund (RGF), European Regional Development Fund (ERDF) for 2007 – 2013. This is now moving to the new European Structural and Investment Funds (ESIF) for 2014 – 2020, with EU funding focused to help and drive "support high business growth" (Mellows-Facer, 2011, p.5), through the creation of growth hubs as support networks for local businesses. This strategic leadership works alongside the government to "set out key investment priorities" (Mellows-Facer, 2011, p.5) to drive local economic growth across England (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p.2).

The City of Stoke-on-Trent is made up of "six towns that stretch over a 12-mile corridor" (Mandate for Change, 2011, p.5). These are: Tunstall, Burslem, Hanley, Stoke, Fenton, and Longton which make up 'The Potteries' as shown in Figure 7.

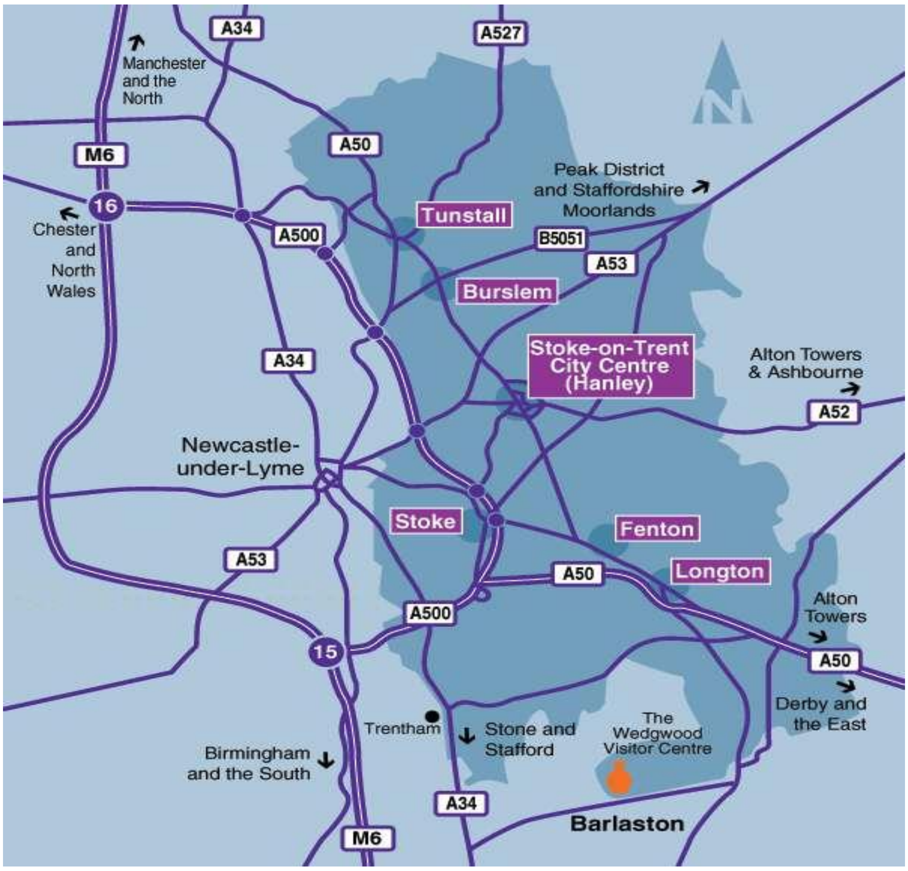


Figure 7: Map of the Potteries (Stoke & Staffordshire LEP Annual Report, 2012)

Stoke-on-Trent has been a historic centre for manufacturing since the late 1700s following the discovery of local coal, iron ore, and clay; "natural materials that contributed to the thriving industrial centre in the 19th and early 20th century" (Mandate for Change, 2011, p.2). As well as the establishment of world-renowned industrial ceramic companies including Wedgwood (c1759), the city also used its presence of coal to support a successful mining industry, in addition to local steel making and manufacturing (Mandate for Change, 2011). This coupled with the "construction of the Trent and Mersey canal (in 1777), shows an early example of economic growth through connectivity" (Mandate for Change, 2011, p.5) as it allowed for the transportation of ceramic products, which resulted in the city's former thriving economy.

Like many previously successful industrial cities, Stoke-on-Trent's potential for economic growth is constrained by a "historic reliance on lower value manufacturing activities" (Stoke-on-Trent & Staffordshire LEP ESIFS, 2014, p.9). The decline of the pottery industry, with much production now being done overseas, combined with complex labour challenges and low skill levels, has led to employment within the city declining significantly and a rise in associated deprivation (Stoke-on-Trent & Staffordshire LEP ESIFS, 2014). The City of Stoke-on-Trent has also taken many years to recover following the recession of the 1980s and 1990s, coupled with the changing demands for goods and services within the city (Mandate for Change, 2011, p.2), as demand rose in new employment areas such as for the service sector opposed to the past reliance on manufacturing industries. Because of these challenges, the "area is underperforming economically relative to the EU average" (Stoke-on-Trent & Staffordshire LEP ESIFS, 2014, p.9), which has negative implications on businesses leading to "below average levels of enterprise and declining business start-up levels" (Stoke-on-Trent & Staffordshire LEP ESIFS, 2014, p.ii) resulting in further economic decline.

The City of Stoke-on-Trent, like many other post-industrial cities, is working towards repurposing itself as a city focused on developing its 'knowledge-based economy' through the role of research and development in generating innovation (Begg, 2002), and as in the Stoke-on-Trent & Staffordshire LEP City Deal submission to Government (SSLEP Annual Report 2014) which is targeting economic restructuring of the city from a manufacturing to a service and research sector economic base.

According to Stoke-on-Trent & Staffordshire Enterprise Partnership (2014, p.2), the LEP draws its members from “senior representatives of vibrant local businesses, local universities, and the area’s local authorities”, all sharing the same vision to ensure that Stoke-on-Trent and Staffordshire becomes an economic powerhouse driven by the transformation of Stoke-on-Trent into a competitive core city through accelerated growth within the urban centres (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014). From this, key objectives of the Stoke-on-Trent and Staffordshire LEP have been created as a driving force for growth, including; the creation of a core city with a strong and competitive city centre brand, a connected county building on its central location, connectivity links and sector growth to ensure globally competitive innovation, investment and enterprise led expansion and finally a skilled workforce, building on the skills needed for the growing employment sectors within the city (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014). All of which build on the shared priority for councils and LEPs to create more jobs for local people and to encourage economic growth within urban centres, and can be achieved through the current projects and strategies in place within Stoke-on-Trent. Through the abundance of on-going regeneration projects including the major redevelopment of the city centre, Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014) works with the intention of “making the city more attractive for inward investment,” (City of Stoke-on-Trent, 2014, p.3). This study will focus on and assess priority sectors which are identified by UK Government to give comparison of performance between regional LEPs. The Stoke-on-Trent & Staffordshire LEP’s objective of business support and growth are developed around employment opportunities tailored with energy generation within Stoke-on-Trent, based primarily upon the ‘Powerhouse Central’ proposal.

The LEPs focus on energy generation links to the Stoke-on-Trent and Staffordshire City Deal as awarded in March 2015, is based around the “emerging energy and renewable growth sector” (Stoke-on-Trent & Staffordshire City Deal, 2014, p.2) within the local area taking advantage of the area’s natural resources in order to create the “UK’s first at-scale low-carbon” (Stoke-on-Trent & Staffordshire City Deal, 2014, p.2) deep geothermal district heating network”. This deal is based around four areas linking to the City Deal - branded as ‘Powerhouse Central’ which focuses on the “deep geothermal district heating network, business support through innovation, the creation of Keele University’s Smart Energy Network Demonstrator, and an advanced manufacturing and engineering skills hub” (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p. 11). The City Deal as awarded in March 2015 receives funding from a variety of sources for this project such as EU programmes such as from the ERDF and ESIF funding routes, with an allocation of £141.53 million to spend during the period of 2014-2020 (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014). This growth strategy will focus on the themes of “Innovation, Small-Medium Enterprise Competitiveness, Place and Environment, and Skills, Employment and Social Inclusion” (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p. 13).

The district heat network proposes the creation of jobs as well as the “lowering of energy costs by 10%” from it becomes operational for a project costed period of 25 years, (Stoke-on-Trent & Staffordshire City Deal, 2014, p.2) to help provide an integrated approach to energy security (Stoke-on-Trent & Staffordshire City Deal, 2014). The City Deal proposes a partnership with Keele University to provide a firm foundation that will help strengthen opportunities and engage with university partnership initiatives to help “provide a strong base of research and innovation assets on which to build in the future” (Stoke-on-Trent & Staffordshire LEP ESIFS, p.18). The UK government encourages stronger links between universities and private businesses at regional and sub-regional levels (Boddy & Parkinson, 2004), as this relationship helps build upon the knowledge-based economy within the area by strengthening innovation techniques through knowledge transfer. Businesses will also get the required support through growth hubs aiming to “support businesses as they develop, whilst generating an environment and culture in which organisations can innovate and be enterprising” (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p. 15). Innovation towards growth within the Stoke-on-Trent and Staffordshire LEP area will help to engage businesses and reinforce the need for improved skills, to ensure that local people can access the opportunities within the local economy both in terms of secure energy supply and better job opportunity (Stoke-on-Trent &

Staffordshire City Deal, 2014).

From this, the ‘Powerhouse Central’ proposal sees the creation of “20,000 jobs over the next 10 years” (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p. 10). The Stoke-on-Trent and Staffordshire LEP believe that the “future prosperity of the Stoke-on-Trent and Staffordshire economy depends on growth and competitiveness within its business base” (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014, p. 6).

The previous Regional Development Agency (RDA) model of which there were 9, (examples being Advantage West Midlands, Yorkshire Forward, One North East) were viewed as being purely public sector based by local business communities; they also had synergies with other cross EU support models and thus was intertwined with EU Commission funding and EU wide programmes. The present geographical LEP models have no direct comparable public and private sector development model in place across the rest of the EU. This has created issues with recognition in EU Commission processes when ERDF (European Regional Development Funding) & ESIF (European Structural Investment Funding) programmes were in development as LEPs as a localised vehicle were not initially recognised in the EU Commission.

Support for this energy focus through District Heat and SMART networks is aligned with EU Energy Policy of 2014 which postulates the need to modernise and develop energy grids to cope with growing demand for energy, and to use more diverse and none interrelated resource mixes to gain better energy supply security “to make the market more fluid” (EU Energy Policy 2014, 2014, p. 6). This policy goes on to describe how the European Union gives consumers, both public and industry, high levels of protection by “protecting vulnerable consumers, increasing the regulatory powers of supervisory authorities and their ability to impose sanctions and make bills easier to understand” (EU Energy Policy 2014, 2014, p. 9). Protecting the end user in regard to service and security of supply is a viewed as crucial in the EU Energy Policy of 2014.

The ability of deploying renewable low carbon technology in updating the EU generation mix is viewed in the EU Energy Policy document of 2014 as a major contributing aspect to European economic activity and a leadership position globally. This also extends to energy efficiency measures being implemented into the building fabric across Europe – with a view that “2 million jobs could be created by 2020 if Europe’s energy-saving objectives are achieved” (EU Energy Policy, 2014, p.11). This would result in a yearly 38 Billion Euro energy bill saving from 2014 to 2020 for a yearly investment of 24 Billion Euro on insulation, energy management and control systems – in this case referring to SMART systems. The policy rightly postulates that Energy efficiency therefore is an important market that gives European leadership new green jobs with over 4 million employed in the sector by 2020 and, high added-value exports.

The importance of energy security, or rather how easily the market can be disrupted and thus affect the commercial and residential population has been shown by the situation in the Ukraine. Outlined in the paper by Goldthau and Boersma on the Ukraine – Russia situation (Goldthau & Boersma, 2014) the political situation between the Ukraine and Russia resulted in a quasi-state of war developing on the Ukrainian eastern border and the further annexation of the Crimea by Russia in March 2014 (Van de Graaf & Colgan, 2017) which brought tension into the fuel markets. The EU Energy Policy of 2014 gives the strategy focus to “diversify sources of external energy supply, modernising energy production in the EU, completing the internal energy market and moderating demand” (EU Energy Policy 2014, 2014, p. 14). What it also considers is that it is necessary for better coordination of decision making between national energy policies and their deployment. This now is brought into question for the UK with the decision to leave the European Union from the June 2016 EU Referendum, with the UK, dependent on the future “leaving deal” it may or may not stay aligned in energy policy or make its own way – which whilst this could allow advantageous dynamics to come in the marketplace could also bring disadvantages in the consideration of security of supply if we are heavily dependent on external support.

The UK is in need of a fundamental change in how it develops support programmes into bringing higher levels of innovation into Low Carbon enterprise growth as it is discussed in the research paper *"Low Carbon innovation and enterprise growth in the UK: Challenges of a place-blind policy mix*" it is discussed that the UK is found lacking in the coherence and consistency of its low carbon innovation policy, thus creating uncertainty. This is affecting the fundamentals of the finance investment market and access to private sector investment (Elsevier, 2016, p.264), with discussions surrounding the lack of cohesion in policies which are frequently about supporting growth strategies through LEPs, and not about supporting sustainable development. It is seen that innovation across economic sectors is key in resolving a 'trilemma' of cost, carbon and security of energy supplies. The stimulation of low carbon innovation is deeply complicated and has many facets requiring high levels of co-ordination in regard to social involvement, policy development and delivery, covering energy generation, power transmission, pricing, regulatory frameworks, reducing pollution and also to driving competition across industry and also growth in regional development.

An example of uncertainty at a national level on this trilemma is that the UK Committee on Climate Change, which was advising the UK Government, noted that in 2010 the objective set by the 2008 Climate Change Act had high levels of uncertainty surrounding the path from 2020 to 2050, where the UK is committed to an 80% reduction in greenhouse gas emissions. This uncertainty was related to the assumptions that had been made regarding the availability of the technology which would be required to achieve these targets (Committee on Climate Change, 2010). To counter this as a riposte, DECC launched its 2011 Carbon Plan which stressed that to meet the 2008 requirements in the 2020 to 2050 timeline the UK would need to dramatically increase energy efficiency and to decarbonise electricity through the uptake of renewables and nuclear power. This view then became politicised by the new Prime Minister David Cameron in May 2010 that the "Coalition Government would be the greenest government ever", and the UK Plan for Growth clearly identified low carbon energy as one of the growth sectors where the UK should aspire to become a 'world leader' (HM Treasury/BIS, 2011).

2.2 - Energy Opportunities

The Stoke and Staffordshire Local Enterprise Partnership (SSLEP) in its "Powerhouse Central" proposal to Central Government developed a unique "Decentralised Energy" offering as its key focus to drive economic regeneration. The energy prospects for the Decentralised Energy supported the District Heat Network (DHN) project effectively whilst also utilising existing proven technology systems which are viewed as a low risk off-the-shelf and spade-ready development to reduce deployment issues by DECC and BIS (now BEIS), and especially by the Treasury Office the Government Departments that were key in developing and signing of the SSLEP City Deal package. This fitted with Central Government's requirements as outlined in the DECC 2012 Heat Strategy which was supporting a greater policy of DHNs being rolled out cross the UK, with some 115 projects being considered and supported by the DECC HNDU (Heat Network Development Unit), (Appendix 1 shows the full listing of the 115 Local Authorities supported in round 1 to 4 by HNDU). A full listing of the Local Authorities who have received funding from DECCs HNDU (Heat Network Development Unit) is available in Appendix 1, a sample of the listing including Stoke-on-Trent City Council is shown in Figure 8.

Heat Networks Delivery Unit (HNDU)

Successful local authorities	Round 1	Round 2	City Deal Projects	Round 3	Round 4	Total
Stoke-on-Trent City Council		£224,450				£224,450
Stratford-on-Avon District Council					£30,150	£30,150
Sunderland City Council				£80,400	£33,500	£113,900
Swindon Borough Council				£120,600		£120,600
Tameside Metropolitan Borough Council				£40,200		£40,200
Trafford Borough Council					£15,000	£15,000
Wakefield City Metropolitan District Council		£36,850			£73,650	£110,500
Warrington Borough Council		£80,400				£80,400
Warwick District Council				£30,000		£30,000
Wiltshire Council		£53,600		£10,000	£26,666	£90,266
Woking Borough Council				£108,429		£108,429
Wychavon District Council				£53,600		£53,600
Wycombe District Council	£34,000					£34,000
Total	**£1,954,430**	**£2,183,215**	**£295,330**	**£2,265,604**	**£2,983,369**	**£9,681,948**

Contact
For further information, please contact the Heat Networks Delivery Unit on:
hndu@decc.gsi.gov.uk
https://www.gov.uk/government/publications/heat-networks-funding-stream-application-and-guidance-pack

Figure 8: DECC HNDU Support Programme for DHN Technical Feasibility Studies (DECC, 2016)

The Figure 8 listing of HNDU supported projects shows Stoke-on-Trent received £224,450 in Round;

this is in addition to early self-financed studies carried out pre-the HNDU programme.

As of March 2015, the Stoke-on-Trent DHN was viewed by the DECC (now BEIS) HNDU as the lead in this pipeline of projects (due to its maturity and level of feasibility and geotechnical studies completed) by some 18 months. At this time the associated Powerhouse Central City Deal economic package was agreed, signed off and finance transferred from Central Government into a “holding” account held by Stoke-on-Trent City Council and overseen by the Stoke and Staffordshire LEP. It was part of the agreed City Deal package agreement with DECC, BIS, and Treasury Office in London, that the Stoke DHN project should be conventional and utilising present state technology levels. Therefore, the core technology barrier for the Stoke DHN can be viewed as be low risk in terms of technical failure and commercially (Stoke-on-Trent and Staffordshire LEP: City Deal. 2014).

The need to de-risk by using conventional or off-the-shelf technology is a key part of the DECC Heat Strategy of 2012. For DECC a counter to this is the Keele University Smart Energy Network Demonstrator (SEND) project, which by its nature is to be a “demonstrator” for new and emerging technologies. The SEND project also allows for research into the social effects of Smart Networks as part of the demonstrator will be conventional whilst utilising the emerging Smart Grid technology platforms now coming into being.

The Keele University SEND project had its genesis due to many factors, but key drivers were:

Internal drivers

- A need to update or replace its energy and power infrastructure which related to 1950s and 1960’s University buildings,
- A need for Keele University to meets its Carbon Management Targets which are aligned to UK legal Carbon Reduction targets of a 34% reduction by 2020 and an 80% reduction by 2050 (against the 1990 baseline),
- A need to gain substantial energy efficiency gains to affect a real reduction in energy expenditure. It was calculated by Keele University Estates and presented to the SSLEP that if the infrastructure upgrades were not pursued that its energy costs would double by 2020 compared to a 2010 baseline using DECC Fuel Price projections as in DUKES Fuel

Price projections in 2010.

External drivers

- National shortage of working/practical experience to support quality design and research of Smart Energy Network Demonstrator (SEND).
- Reliance on Computerised “theoretical” modelling.
- Existing markets driven to maximise Returns on Existing Global Energy Sources and Solutions, which don’t necessarily align to local needs.
- Shortages in Future Energy Resources not an evident feature of current supply market.
- National Strategies focus on greening the National Grid, which does not assist organisations in directly reducing their CO2 Emissions.

These external drivers were of great interest to DECC and BIS in Whitehall in the SSLEP “Powerhouse Central” City Deal submission as it fitted with the focus of UK Energy Policy and the DECC 2012 Heat Strategy. Whitehall saw the opportunity for other Local Authorities, through the HNDU programme, to be able to undertake learning by SEND that had a national dimension as Keele University essentially represented a small-town community of some 12,000 people that could be isolated off the national grid system. The operational side of the Keele SEND will be designed so that it can be subjected to software and hardware system testing that could be spun out into the national context where it was needed due to the national infrastructure upgrade and replacement needs already described.

Therefore, decentralised energy opportunities that fall within a LEP area could be wide and diverse – in the Stoke & Staffordshire LEP region there are energy opportunities that can be characterised as being Low Carbon Renewable to fossil fuel related; the wind and solar aspect have been quantified in Stoke-on-Trent Renewable and Low Carbon energy opportunities studies as carried out in the period 2008 to 2011. This study of renewable opportunities informed the city council on approaches for its Energy Company Obligations (ECO) projects (CESP, Warm Zone, Warm front into ECO & Green Deal) in the period 2010 through 2013 that enabled the City Council to obtain finance direct from energy producers such as EoN, SSE, Npower for a range of residential building improvements from insulation to solar panel fitment programmes on its social housing stock using the solar orientation data (Green Deal and Beyond: Stoke-on-Trent City Council 2012 URL: http://webapps.stoke.gov.uk/uploadedfiles/Green_Deal_and_Beyond Housing_Retrofit_Managing_ECO_investment_and_Green_Deal.pdf)

2.2.1 - Wind Potential

The geographic topography of the Stoke and Staffordshire region means that there are a number of sites that have wind speeds of over 6.5m/s at 45m vertical height – these tend to lie over the North-East area of the region in the Staffordshire Moorlands as from the DECC NOABL national wind speed database (DECC NOABL Web-based Interactive Wind Map 2013), where NOABL stands for Numerical Objective Analysis of Boundary Layer. This 6.5m/s average wind speed is an accepted requirement for wind turbines over the 250kW generation range by financial institutions. Figure 9 shows the wind speed map at 45m from the BGS GIS Wind Speed database for >250kW turbines as in DECC guidance for the Stoke-on-Trent City Council area.

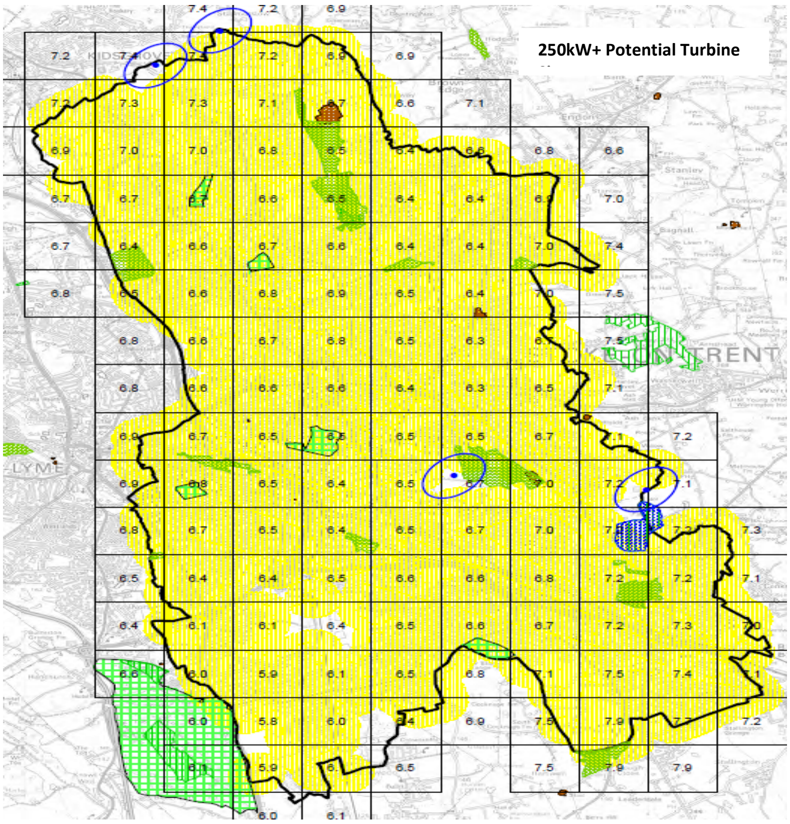


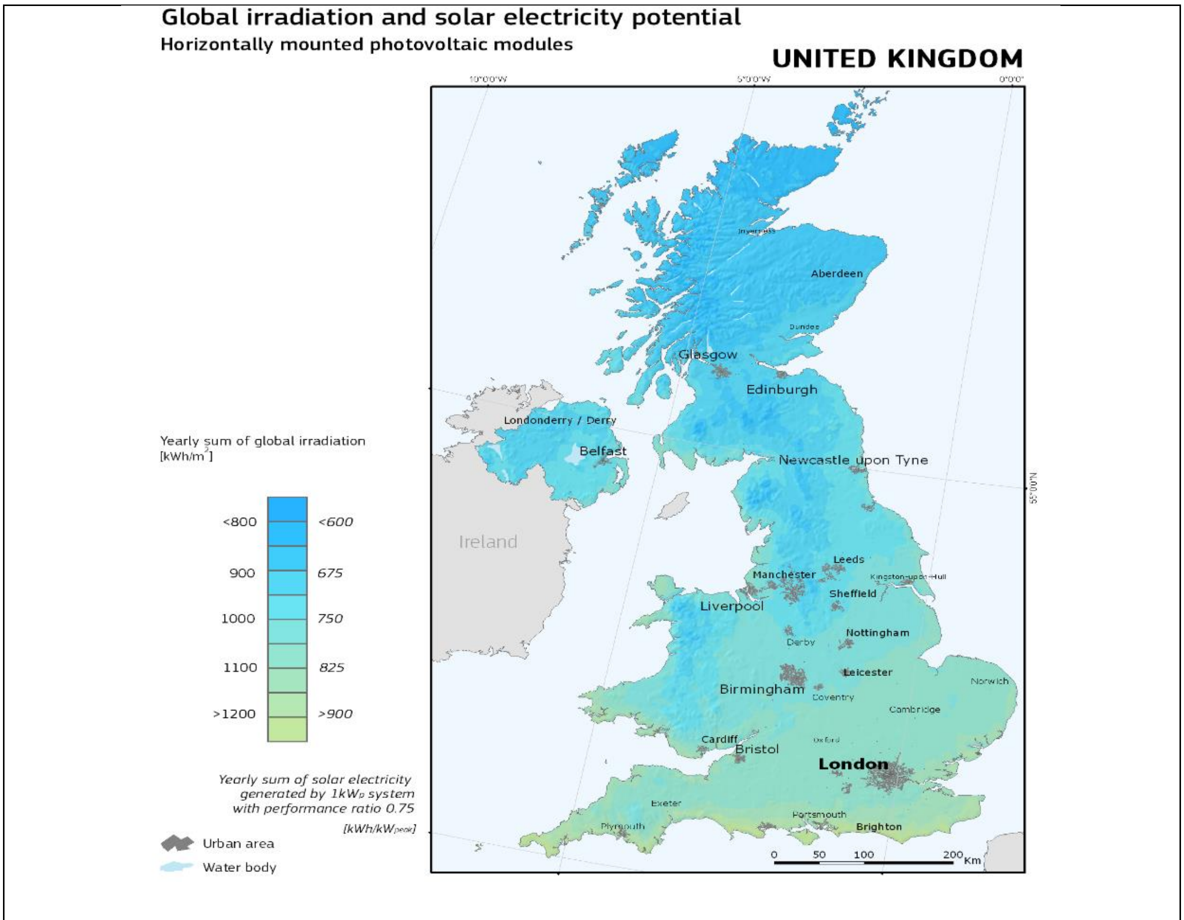
Figure 9: Wind Speed Map for Stoke-on-Trent at 45m - BGS Wind Speed GIS Database

The main issue here is that most of the +7m/s potential sites are in the Moorlands area in the Peak District National Park which has regulatory planning limitations on wind turbine developments. In the urban situation, there are similar planning conditions such as visual impact, noise, flicker that limit the availability of potential site considerably. Even when urban sites are identified local public resistance then has nullified developments. Figure 9 also identifies the 4-possible site for +250kW turbines taking into account current planning and consent considerations.

2.2.2 - Solar

Solar has seen a level of deployment in the Stoke and Staffordshire LEP aligned with the Local Authorities take up of Government driven funding options such as "ECO" the "Energy Company Obligation" – which is a legal requirement for national power generation companies to give financial support for solar deployment programmes specifically into social housing stock properties. The aim of ECO as defined in the online Government website URL https://www.gov.uk/energy-company-obligation for "Help from your energy supplier: The Affordable Warmth Obligation" dated 22nd July 2016.

Solar ability reduces with increasing latitude, but if the correct orientation can be obtained with the decreasing cost of solar PV panel fitment then a financial gain can be gained in the Stoke and Staffordshire LEP region; particularly in properties that have a suitable south facing orientation. The EU Commission has developed and supports a solar incidence tool called PVGIS – Photovoltaic Geographical Information System which gives specific data by Longitude and Latitude and place for Solar power levels by month. This is available on URL http://re.jrc.ec.europa.eu/pvgis/ - Figure 10 gives the solar average for the whole of the UK in kWh/m^2 pa.



http://re.jrc.ec.europa.eu/pvgis/cmaps/eu_cmsaf_hor/G_hor_UK.png

Figure 10: EU JRC PVGIS – UK Solar Power Levels (EU JRC PVGIS, 2016)

Using the EU PVIS system the solar levels for the Stoke-on-Trent area is found to be 1170 kWh/m2 pa with a potential electrical generation level 903 kWh pa for a 1kW system after considering conversion losses from a crystalline silicon type panel (ref system access as of November 2016).

2.2.3 - Biomass and Biogas

Biomass as organic matter can be used to provide solid, gaseous and liquid biofuels in the form as wood logs, pellets, biomethane, bioethanol. These varied forms create viable fuel feedstock for the generation of power by various conversion technologies.

The market for biomass-based heat is dominated by small scale units for providing thermal energy for cooking and for space heating from mainly solid wood fuels in developing countries, as it has been used by humans for thousands of years. In industrialised countries, the heat market is determined by small and large-scale devices mainly for room heating purpose based on woody solid biofuels; the latter is partly realised in combined heat and power (CHP) systems. According to a world market status report undertaken by Kaltshmitt and Janczik in 2015 biomass to power is on the rise globally, through the application of a variety of conversion technologies biomass is a widely used renewable energy source in the global market.

Their research shows that even though biomass-based heat provision is fragmentary they view that global heat provision of 23.7x1018 J is derived from a solid biofuel with an energy content of 59.3x1018 J in 2014 Kaltshmitt and Janczik (2015). For Europe in 2014 they study shows that solid biofuels used for electrical generation has an installed capacity of 29GW producing around 150 TWh. This electrical generation is dominated by five main bio power producers Germany, Finland, the UK, Sweden and Poland. What they go on to show is that these countries, other than the UK, from these bio power plants also give a useable heat output distributed by district heat systems used by both industry as well as residential users. This is not the case in the UK from its large bio power plants, as there is no distribution capability into district heat networks other than presently in 2014 a handful of aging systems – but nothing systematic as found elsewhere across Europe.

As well as solid biofuel, which in the main is wood chip or wood pellet feedstock systems, the other main forms of organic power comes in the form of biogas from anaerobic decomposition. In this process known as anaerobic digestion in which a biogas with a methane CH_4 content of from 45% to 65% is generated by the decomposition process. The market status report by Kaltshmitt and Janczik (2015) has the biogas-based electricity generation within the EU is estimated to be 55TWh in 2014 from an installed capacity of 8.8GW. Of this, Germany has the highest proportion at 3.9GW. The review found that the UK is undergoing a rapid increase in AD plant capacity. With a high proportion to having a CHP capability to both generate electrical power, but also to utilise the heat produced in local industry or residential networks. Biomass is particularly suited to heat network supply as proven in other European countries, particularly in Scandinavia and so is of interest for this research piece.

2.2.4 - Waste Material

Waste material is considered to be an energy feedstock either, through its biological degradation producing combustible gas or by direct combustion processes.

Biogas generation, if arising from organic food waste material, can be considered as having a good potential for the recovery of waste materials as a fuel feedstock. In the UK the Department for Environment Food and Rural Affairs (DEFRA) and the Environment Agency (EA) promotes the "Waste Hierarchy", as detailed in the DEFRA waste guidance document of 2011 to support the Waste (England and Wales) Regulations 2011. The DEFRA Waste hierarchy is shown in Figure 11.

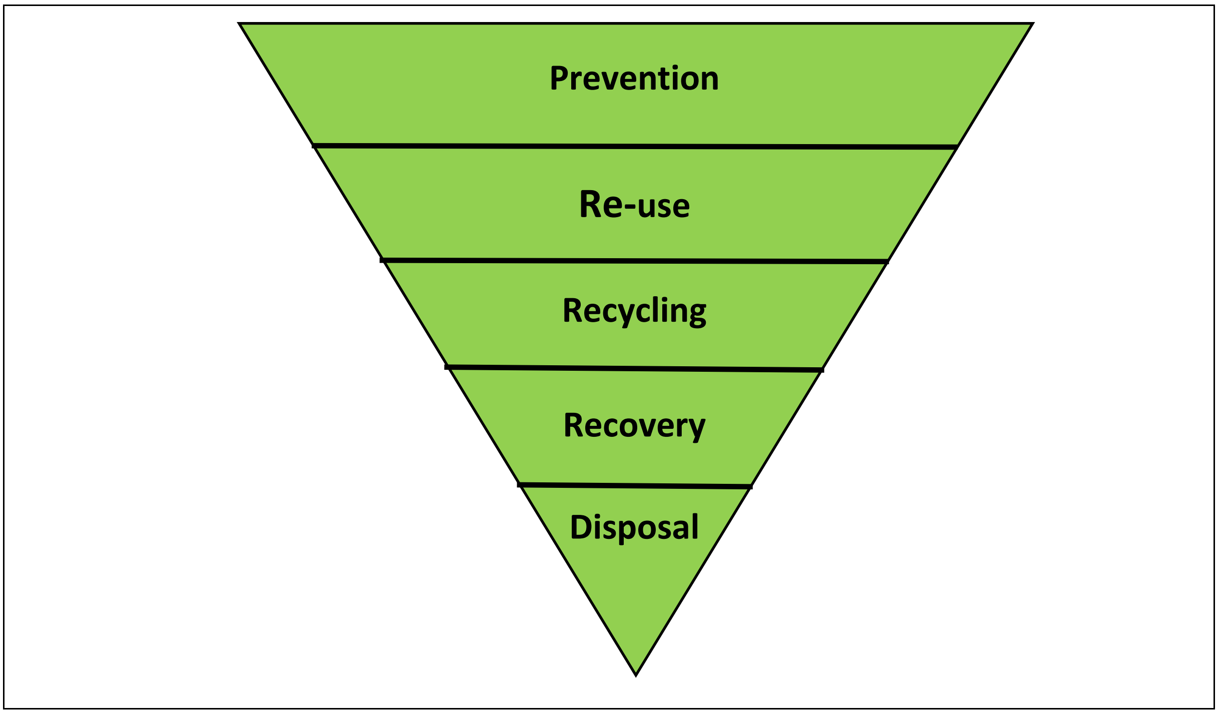


Figure 11: UK Waste Hierarchy - DEFRA 2011

Within the DEFRA hierarchy, the level marked as "recovery" covers the aspect of utilisation of suitable waste materials as fuel feedstock. Waste materials are in a segregated form; isolating out the organics such as waste foodstuffs / biomass from the in-organics such as plastics / metals / glass. In such segregated forms differing individual fuel feedstock routes can then be followed.

The DEFRA hierarchy guidance of 2011 outlines a range of energy recovery technology groups, these having been assessed by the EA as what is referred to as "Best Acceptable Techniques" (BAT). These would be viewed as acceptable by regulatory bodies such the EA and Local Authorities when an operator applies for planning and operational permitting to build and run a facility.

For organics, biogas, or bio-oil production the technology groupings such as anaerobic generation (AD) and gasification / pyrolysis processes are now becoming established in the UK. Anaerobic digestion is now becoming increasingly popular with around 125 AD plants in operation which handle waste municipal and commercial waste feedstocks according to the Anaerobic Digestion and Biogas Association (ADBA) plant listing as from Quarter 2 2016.

If the waste is not segregated (i.e. not separated into the UK Government specified standard groupings) it is characterised by the EA as Municipal Solid Waste (MSW) if from residential mixed collections, and Commercial and Industrial waste (C&I) if from industrial sources. In the UK MSW and C&I wastes have been landfilled for many years. This is now under planned decline due to financial pressures from the escalating Landfill Tax regime established as part of the Waste and Emissions Trading Act (WET Act) of 2003. From the landfills in the UK that are both operating or in a closed position, many are extracting landfill gas emissions that comprise mainly of methane gas which is utilised on site by gas engines stations to produce electricity supplied to the grid and in some gases heat for near site use.

2.2.5 - Geothermal Energy

Geothermal energy development in the UK has been limited, partly due to the lack of high temperature resources, but also due to the availability of cheap fossil fuels, such as North Sea natural gas from the late 1970’s until the late 1990’s. In the wake of the 1973 oil crises the Department of Energy examined the potential for exploiting geothermal energy in the United Kingdom on a commercial basis. Several regions of the country were identified, but interest in developing them was lost as oil fuel prices fell, as described by Busby J (2013).

When comparisons are made to countries with a similar geological setting, it is clear that the UK is underutilising this potential, as discussed in the "Research Atlas: Renewable Energy Sources – Geothermal Energy" by the Energy Research Centre (2013).

Deep geothermal energy is energy stored in the form of heat beneath the earth's surface. Between 45% to 85% of this heat being the result of radioactive decay of isotopes such as Uranium, Thorium and Potassium, in the crust and mantle. The balance of this heat is the result of the primordial energy, resulting from planetary accretion – in that the earth is cooling very slowly with the mantle having only cooled by between 300 to 350oC in the last 3 billion years with the core at around 4,000oC according to Busby J (2013).

A clear distinction needs to be made between deep geothermal and shallow geothermal energy. Shallow geothermal is the result of impinging solar radiation energy transfer into the earth's surface and interacts to a ground depth of 10m to 15m. The ground surface to this depth acts as a heat store and can be exploited in a number of different ways. This heat can be utilised by ground source heat pumps into residential or specific building projects not with heat networks.

Deep geothermal energy is utilised in heat networks. Its potential as a heat resource in the UK was investigated by a programme funded by the UK government and the European Commission that ran from the mid-1970s until the early 1990s, called the Hot Dry Rock project. Through this programme drilling took place into the Carnmenellis granite of Cornwall at the Rosemanowes Quarry, near Penryn, as discussed by Busby J in his research "Geothermal Prospects in the United Kingdom" (2010). The UK deep geothermal energy potential is illustrated in Figure 12, a heat flow map of the UK according to Busby J (2010).

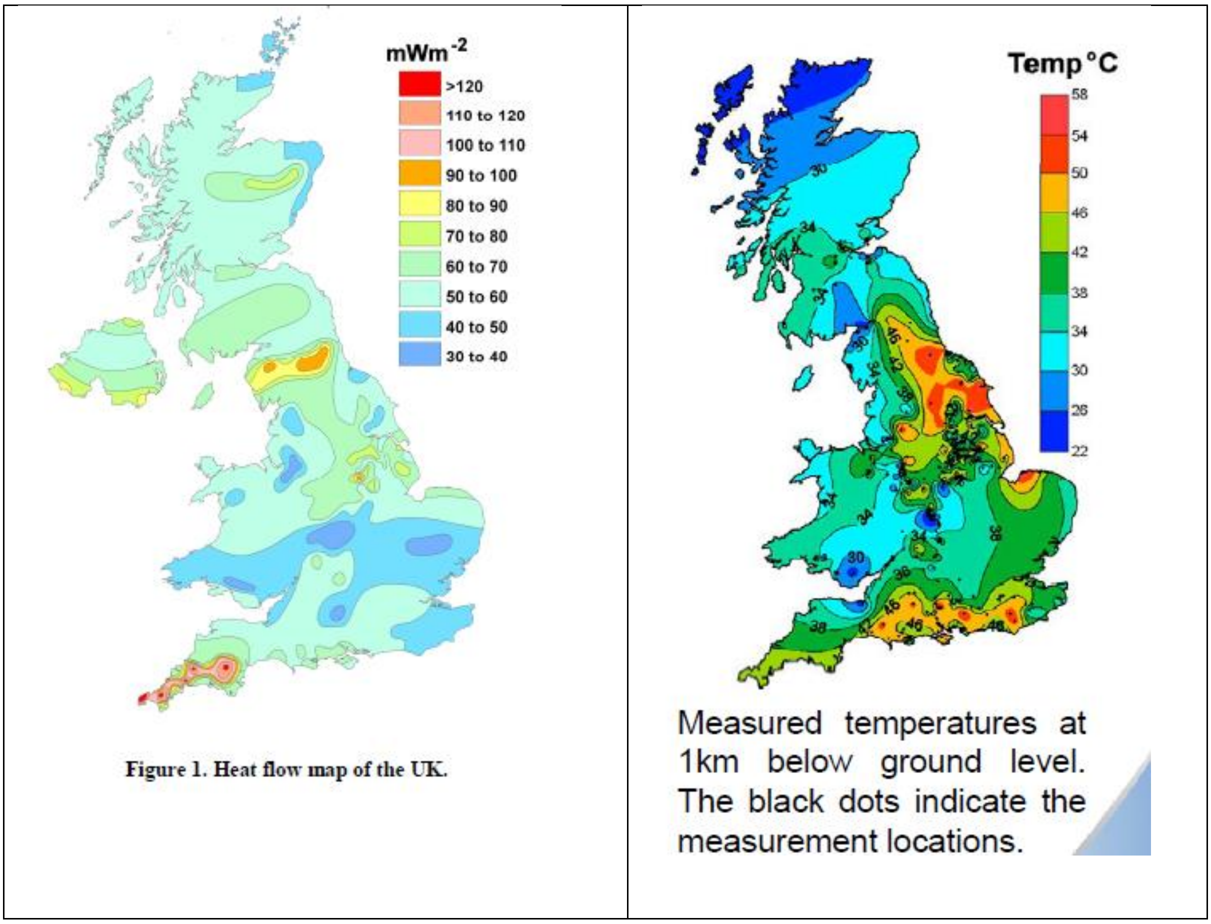


Figure 12: Heat flow and Temperature gradient map of the UK. Busby J (2010)

According to Allen, Gale & Price (1985) the average geothermal gradient in the UK is 26oC per km of depth with the heat being held in aquifer basin systems, such as related to the Sherwood Sandstone group and the Permian sands found in the top and base of the aquifer formations in the Cheshire Basin centred under Crewe.

Therefore, aquifer based schemes holding groundwater in Permo-Triassic sandstones in the UK has the potential to provide an exploitable geothermal resource at depths of between 1 and 3 km.

In line with the research of Allen, Gale & Price (1985) in the early 1980's the UK Department of Energy technically examined basins of principal interest including East Yorkshire and Lincolnshire, Wessex, Worcester, Cheshire, West Lancashire, Carlisle, and basins in Northern Ireland. Building on this work, Southampton City Council in 1986 created the UK's first geothermal power scheme based on the Wessex Basin aquifers for geothermal power. The Southampton scheme by 2007 to be a system of 11km of network piping producing some 40GWh of heat, 22GWh of electrical power and also 8GWh of cooling to over 1,000 residential properties, the West Quay shopping area and the Royal South Hants Hospital and other public buildings as described in a Greenpeace case study: Southampton (2007).

Renewed interest in the geothermal energy resource potential of the UK rose again in the 2000s, as a potential way of addressing some of the UK's "energy gap".

The Renewable Energy Association (REA) outlined that an independent technical research piece by Sinclair Knight Merz (SKM) in 2012 shows that the UK deep geothermal resource has potential to produce up to 20% of UK electricity and heat requirements from the regional aquifer systems giving the heat and power potential as shown in Figure 13.

Region	Heat MWth	Heat equivalence	Power MWe	Power equivalence
South West	13,000	6.5 million homes annual heat demand	4,000	1.25x Hinkley C nuclear power stations
North East	9,000	4.5 million homes annual heat demand	4,000	1.25x Hinkley C nuclear power stations
The Lake District	8,000	4 million homes annual heat demand	2,300	0.6x Hinkley C nuclear power stations
Wessex Basin	33,000	16.5 million homes annual heat demand	Not assessed	
Cheshire Basin	14,000	7 million homes annual heat demand	Not assessed	
East of England	12,000	6 million homes annual heat demand	Not assessed	
Worcester Basin	6,700	3.35 million homes annual heat demand	Not assessed	
Larne Basin	1,000	0.5 million homes annual heat demand	Not assessed	

Figure 13: UK Geothermal Heat and Power potential. SKM Research. (2012)

Studies into renewable energy options undertaken at Stoke-on-Trent City Council in the period 2008 to 2012 looked at the potential of deep geothermal. This then resulted in the proposal of deep geothermal energy to power the Stoke-on-Trent district heat network (DHN) (Stoke-on-Trent & Staffordshire Enterprise Partnership, 2014). The proposal for Stoke would see a 2.5 to 3km drill in the centre of the city to access a potential 45GWh of heat for distribution in the proposed heat network phase 1, (Energy & Climate Change Technical Paper – SOTCC & NULBC, 2015).

But a fundamental question to be asked and defined is what is Decentralised Energy?

2.3 - <u>What is decentralised energy?</u>

Research on the subject of decentralised energy deployment by Chmutina and Goodier (2013) showed that in the case of the decentralised energy initiatives, governance drivers may play a more important role than financial drivers. They found highly supportive institutional frameworks allow the stakeholders to ensure that the schemes enjoy a stable and certain environment – institutional factors such as compliance with international agreements (such as driven by the Kyoto Protocol) lead towards low-carbon energy generation and energy consumption reduction. But as a counter to this Marques et al. (2010) showed that generally "environmental concerns appear not to encourage the use of renewable energy" and that "the larger CO2 emissions, the smaller are the renewable energy commitments", as the countries with high CO2 emissions levels have large proportions of energy generated by fossil fuels; this traditional energy generation benefits from the strong support of industrial lobbying groups that restrain renewable energy deployment. Government regulation and legislation act as an important driver for energy initiatives because of the necessity to comply with them is discussed by Walker et al. (2007) e.g. the compliance with regulations encourages implementation of the projects.

Chmutina, and Goodier (2013) show that a number of towns, cities and communities in the UK have already pioneered unique and effective approaches to more DE systems leading to enhanced GHG reductions. The implementation of these approaches, however, is a long and complicated process that requires not only financial investment but also support from authorities, community engagement and other interconnected factors, that, if underestimated, can negatively affect the outcome of the project.

Despite the increasing amount of literature available on decentralised energy, comprehensive empirical analysis on drivers remains scarce. Watson and Devine-Wright (2011) argue that financial drivers such as policy instruments and procurement mechanisms play the most crucial role in promoting decentralised energy, and it is also viewed by Chumtina and Goodier (2014) that governance drivers play a significant role in DE initiatives.

Technical barriers to decentralised energy deployment cannot be removed on their own as they are frequently highly entwined with other aspects, and often once governance, social and financial barriers are removed, technical barriers, such as localised grid capacity and support infrastructure which is often limited to either a specific power loading or not being able to handle localised generation (i.e. PV solar panels on residential roofs), may often disappear without any specific direct action.

Decentralised energy is the ideal representation of localism in that is produced close to where it will be used, rather than at a large plant elsewhere and sent through the national grid, and when possible or required to export back into the national grid and be a potential revenue earner for the generator and supplier. Local generation reduces transmission losses and lowers carbon emissions. Security of supply is increased nationally as customers don't have to share a supply or rely on relatively few, large and remote power stations, as shown in Figure 14.

There can be economic benefits too, as it is the UK Government's aim that long term decentralised energy should offer more competitive prices than traditional energy as elements will be produced and distributed by locally owned and run Energy Supply Companies (ESCOs). While initial installation costs may be higher, most of the UK Power Infrastructure is now due for replacement or updating, so major investment is due anyway. Market dynamics will be altered with special decentralised energy tariff creating more stable pricing.

For house builders, developers and PFI consortia, decentralised energy is the cost-effective route to achieving carbon targets. This approach to low carbon energy provision gives you the opportunity to promote a locally provided, sustainable, competitive and smarter energy choice as shown in Figure 14 for key attributes of a SMART network.

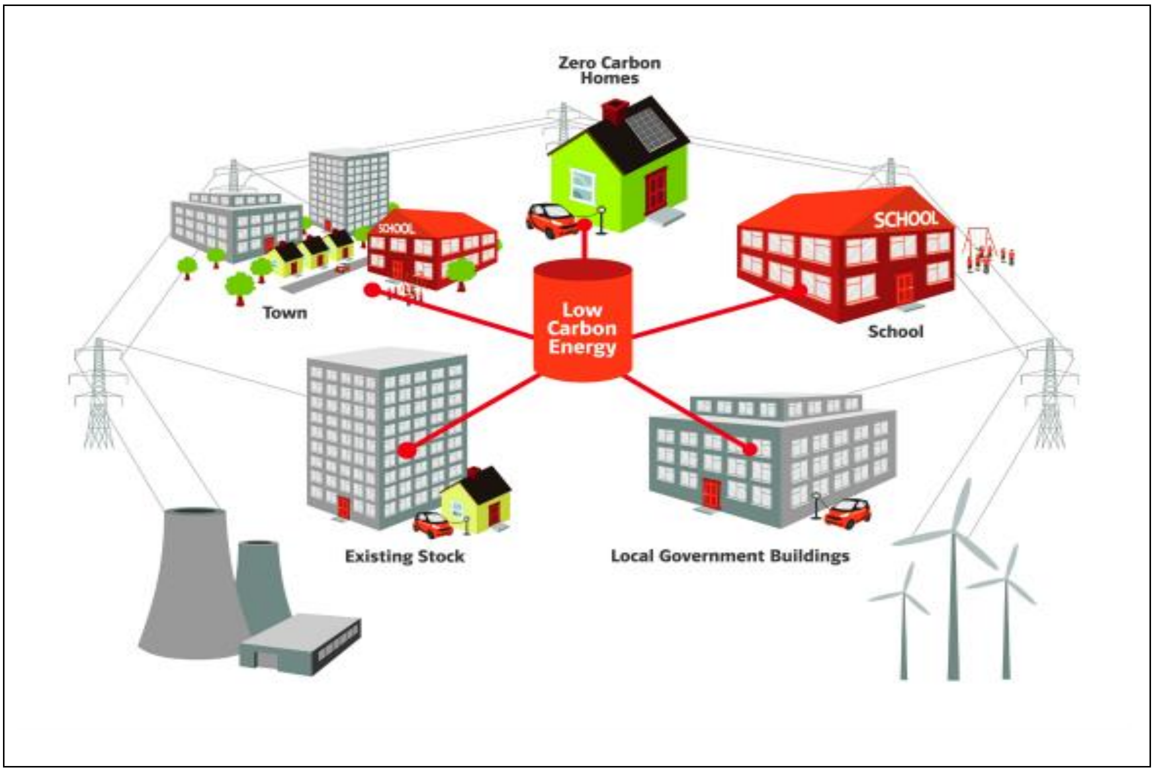


Figure 14: Schematic of Decentralised Energy concept (EoN, 2016)

This study builds on this body literature and background knowledge on the roles of organisations and government support for energy development and the potential energy sources available to examine the case study of decentralised energy potential and development in the City of Stoke-on-Trent.

3. Methodology

3.1 - Research approach

This research is carried out by undertaking an observation of the decision making around the development and implementation of district heat networks.

Therefore, the key questions to be considered from these statements and observations, which are pertinent to this research are:

- How to transform the UK Heat Supply market?
- How to drive supply chain growth into this transformed Heat Supply market?

To this end, the research piece will consider these wider questions through the lens of a case study from the Stoke and Staffordshire Local Enterprise Partnership (LEP) City Deal Energy developments, with the Stoke-on-Trent City Council District Heat Network (DHN) and the Keele University Smart Energy Network Demonstrator (SEND) projects in terms of:

- Strategic policy drivers
- Operational support – national / regional programmes
- Timeliness
- Impact and Power, e.g. who are the stakeholders which are affected who makes the decisions?

In addition, the Stoke-on-Trent developments will be considered in comparison with other International case studies of decentralised energy:

    - Decentralised heat networks in Sweden whilst viewed as a mature market are still developing

- The City of Munich with mixed decentralised energy projects developed to deliver the City's aim to secure its energy and be self-sufficient be

Also, decision making of Local Authority organisations will be considered related to the development and the implementation of decentralised energy and district heating network. This will be through the examination of the relationship and dynamics that come into play in achieving a desirable balance between addressing energy security, infrastructure investment and technical feasibility. This will provide a basis to consider whether decentralised energy, as a part of this balance, can support economic regeneration.

3.1.1 - Observational Case Study

An observation of the planning, consultation and design phase of the Stoke-on-Trent District Heat Network took place between February 2012 and October 2016. Following this observational case study approach allowed for an in-depth appreciation of the present situation of decentralised energy developments in the UK through the governance and operating practices in play between the Stoke and Staffordshire LEP, its stakeholder LA's and Central Government in Whitehall.

A key aspect of this observational study was the examination of the Stoke-on-Trent and Staffordshire Local Enterprise Partnership (SSLEP) City Deal programme as a key pillar for economic regeneration. Particular emphasis was placed on the energy side of the City Deal which is based on the Stoke-on-Trent District Heat Network, DHN, project and the linked Keele University Smart Energy Network Demonstrator via a case study.

The research is undertaken as a desk-top observation study of the decision making and political infrastructure by the author, who was a private sector board member of the Stoke-on-Trent & Staffordshire Local Enterprise Partnership (SSLEP) during this period. Permissions and authorisations were obtained from the SSLEP to undertake this research study on its evolution of the City Deal regeneration submission, called the Powerhouse Central, its passage through the Whitehall process and the subsequent project workup on winning funding. The associated technical factors to the Powerhouse Central submission have been considered through examination of the existing research literature base.

This empirical approach therefore will not be characterised by a heavy review of statistical data or by a statistical survey but is based on observed, as seen, actual experience of the Stoke and Staffordshire Local Enterprise Partnership (SSLEP) and the Whitehall City Deal (the support vehicle provided by government to drive local regeneration projects) process to win funding to support economic regeneration.

In can be argued that if a case-based observational study is founded on such a narrow field its results cannot be extrapolated to fit and entire national situation such as country-wide decentralised energy rollout and deployment. This is particularly relevant here when considering what may be viewed as unique issues specific to the SSLEP situation. Contrary to this, it can be argued that an observational case study provides more realistic responses and experiences than a purely statistical-based piece of research when unique issues are registered and understood in how they affect processes and policy's more widely. This need to identify, register and understand the unique issues is to avoid selection bias (Achen and Sidnal 1989; Geddes 1990); whereby selection bias occurs "when some form of selection process in either the design of the study or the real-world phenomena being studied results in inferences that then suffer from systematic error" (Collier and Mahoney 1996, pg. 59).

3.1.2 - Comparison with European cases

Benchmarking was carried out by reviewing two case studies of decentralised energy (DE) and district heat network (DHN) developments in Europe. These cases were chosen as they are of different spatial scales. Sweden was a national programme, and Munich was a regional development. Both cases had similar features in terms of technology, but key differences existed in organisational structure and stake-holder involvement.

3.1.3 - The Energy Trilemma

The dynamics of developing the approach to successfully achieving economic regeneration through an energy-focussed project, in this case with a core aspect based on decentralised energy and Smart District Heat Network, is viewed as a real example of the policy trilemma situation here concerning balance between Economics vs Social vs Politics (Keay M, 2016) as shown in Figure 15.

The trilemma model is analogous to the Impossible Trinity trilemma of international economics which is described by the NBER Working Paper 10396 on the difficulties of the economic situation when balancing policy of Exchange rates with Monetary Policies and Capital Mobility (NBER Working Paper, 2004).

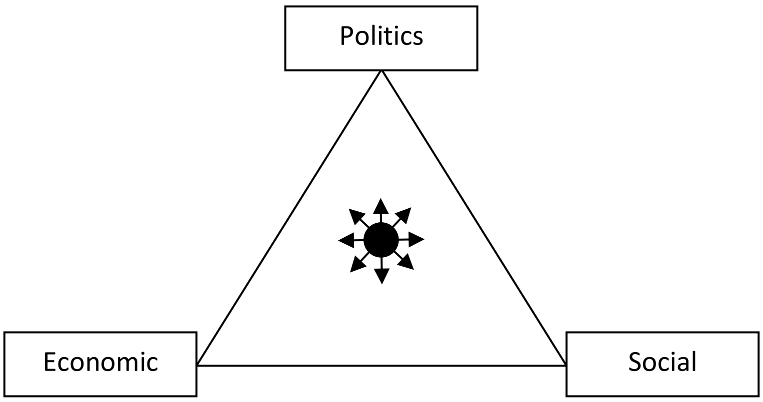


Figure 15: Trilemma situation of Economics vs Social vs Politics

In the Impossible Trinity Trilemma, it is viewed that it is a near impossibility to have all desirable outcomes at the same time with competing constantly varying forces pulling in all directions at once, such that a difficult balancing act must be followed to attempt to give all participant stakeholders a worthwhile outcome and not disenfranchise them by the process.

Therefore, it is part of this study to test, by observation, the development and deployment of economic regeneration strategy based on associated supply chain growth with decentralised energy in the form of a smart district heat network, DHN, technology being implemented.

It can also be viewed that this trilemma has a further dynamic that complicates it further as consideration must be shown towards the aspects of Carbon vs Cost vs Security as in Figure 16.

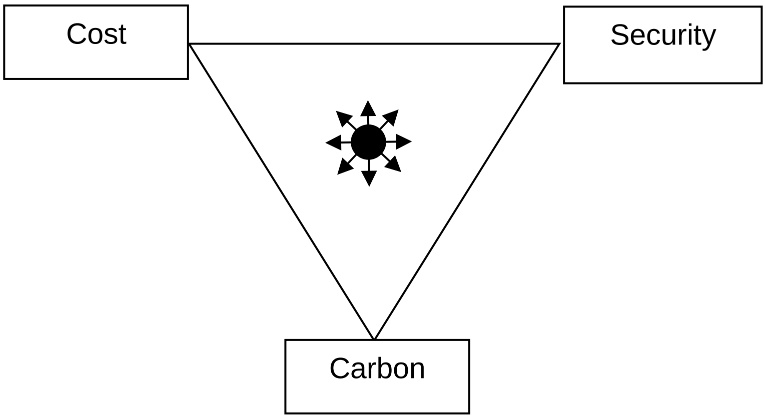


Figure 16: UK Energy Trilemma (DECC UK Energy Investment, 2014)

3.2 - Research Envelope

The research envelope for this research when considering the trilemma of Economics vs Social vs Political as in Figure 15 is influenced by a number of factors:

- changes in Energy Policy since 2000 until the end of March 2017 principally by the UK and as driven by EU Commission Directive and UN Climate Change regulatory commitments,
- changes in Economic Regeneration Policy since 2000 until the end of March 2017 principally by the UK and as driven by EU Commission Directives,
- LEP formation policy – their history and governance,
- Stoke and Staffordshire LEP formation policy – its history and governance development,
- England Energy policy developments which drive technology take up – such as the FITs, Feed in Tariffs for Renewable technology systems, Renewable Obligation Certificates, ECO,
- A need to better understand LEP key performance through indicators which are used as a measure in all programme developments for economic regeneration in Stoke and Staffordshire LEP area. These measures include the extent and value of job creation and to increases in the value of the LEP economy. Specifically, the SSLEP has a target of a 50% increase in the Gross Value Add (GVA) this being the economic measure performance of a

LEP area where the definition of Gross Value Add (GVA) is the measure of the value of goods and services produced in an area, industry or sector of an economy, in economics).

3.2.1 - Ethical and approval considerations

As this research did not involve human participants or access to information relating to individuals no ethical approval was needed. However, permission was sought and granted from the LEP. The researcher during the period from June 2012 to completion of the study held the position of private sector board director on the Stoke and Staffordshire LEP with the remit for Energy and Carbon developments. The study basis was discussed by the LEP Chair and secretariat and passed as acceptable to proceed, a review discussion occurred annually and approval for continuation was given on each occasion. The research activity recorded officially and listed on the members conflict of interest register.

4. Policy and Technology – Development and Drivers

4.1 - Energy and climate change policy development in the EU

Whilst the UK looks to be leaving the European Union body following the 23rd June 2016 referendum vote it will likely still be aligned with the Environmental and Climate Change directives and policies for many years to come as these will be translated into UK Law by the Great Repeal Bill. With the UK being one of the EU leading economic powers along with France and Germany it has been leading in policy development, so it is important to understand the basic timeline of the development of Energy policy in the EU and the earlier structure of the European Community that has led to the UK present policy structure, this is shown in Figure 17 of the timeline of European Energy and Climate Policy as produced by the Institute of International and European Affairs (dated 15th April 2013 as from URL http://www.iiea.com/blogosphere/timeline-of-european-energy-and-climate-policy dated November 2016).

The reality of the resulting policy developments and directives implemented by individual EU countries is an acceptance that Europe is facing a situation of rising energy demand, supply disruption and high volatility in prices. The resulting overarching EU Energy Policy was released in 2014 (URL for download: https://bookshop.europa.eu/en/energy-pbNA0614043/?CatalogCategoryID=sciep2OwkgkAAAE.xjhtLxJz November 2016). This strategy document details a policy that has at its heart, a European Energy Union to ensure secure, affordable and climate friendly energy for citizens and businesses in the EU. Various CO_2 reduction targets are detailed in the policy for set year check points – all the 28 EU states (based on the UK still being an EU member) have agreed to put into legal statute the following:

EU Targets for 2020:

- To reduce Greenhouse gas emissions by a minimum of 20% to 1990 baseline levels,
- To achieve 20% of energy from renewable sources,
- To achieve a 20% increase in Energy efficiency.

EU Targets for 2030:

- To achieve a 40% reduction in Greenhouse gas emissions compared to the 1990 baseline,
- To achieve a minimum of 27% of EU Energy production from renewable sources,
- To achieve a 27-30% increase in Energy efficiency.

EU Target for 2050 is to achieve an 80-95% reduction in Greenhouse gas emissions compared to 1990 baseline levels. The EU Energy Roadmap 2050 document (URL: https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf) shows approaches to achieve this as in Figure 17.

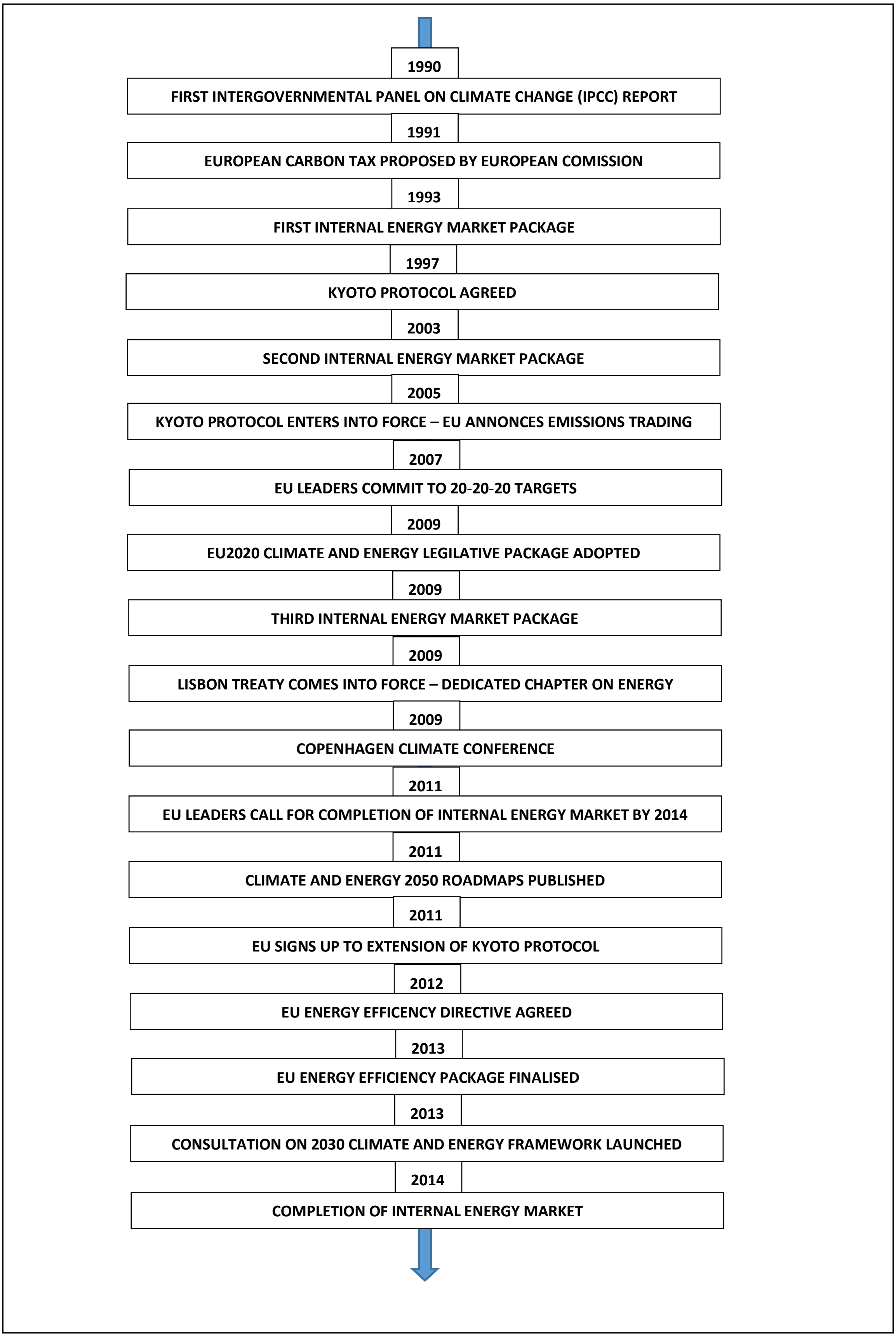


Figure 17: Timeline of European Energy and Climate Policy - EU Energy Roadmap until 2050 (COM, 2011)

From the EU Strategy document (EU Energy Roadmap 2050), it is clear that if dramatic steps are undertaken in regard to energy generation, distribution and usage, linked with increases in Energy Efficiency they gain comparable levels in improved Energy Security and also in terms of balance of payments in that less is spent on "importing" energy in the EU. This last point is crucial as whilst the EU block is viewed as the 2nd largest economic globally in terms of GDP as per the International Monetary Fund GDP listings of 2016 (IMF GDP Listing. 2016), behind the USA with China likely to take the top spot by 2035, the EU is far from self-sufficient in energy resource and provision.

The EU relies upon imports from around the Globe, with it consuming around 20% of the global energy consumption annually. The EU does have a diverse energy resource; it has already utilised a proportion of its available hydro sites with the balance now not viewed as viable either due to cost which could alter over time or due to environmental constraints which likely will not alter in time. Differing states have made strategic decisions over the last 40-50 years to ensure their own energy security.

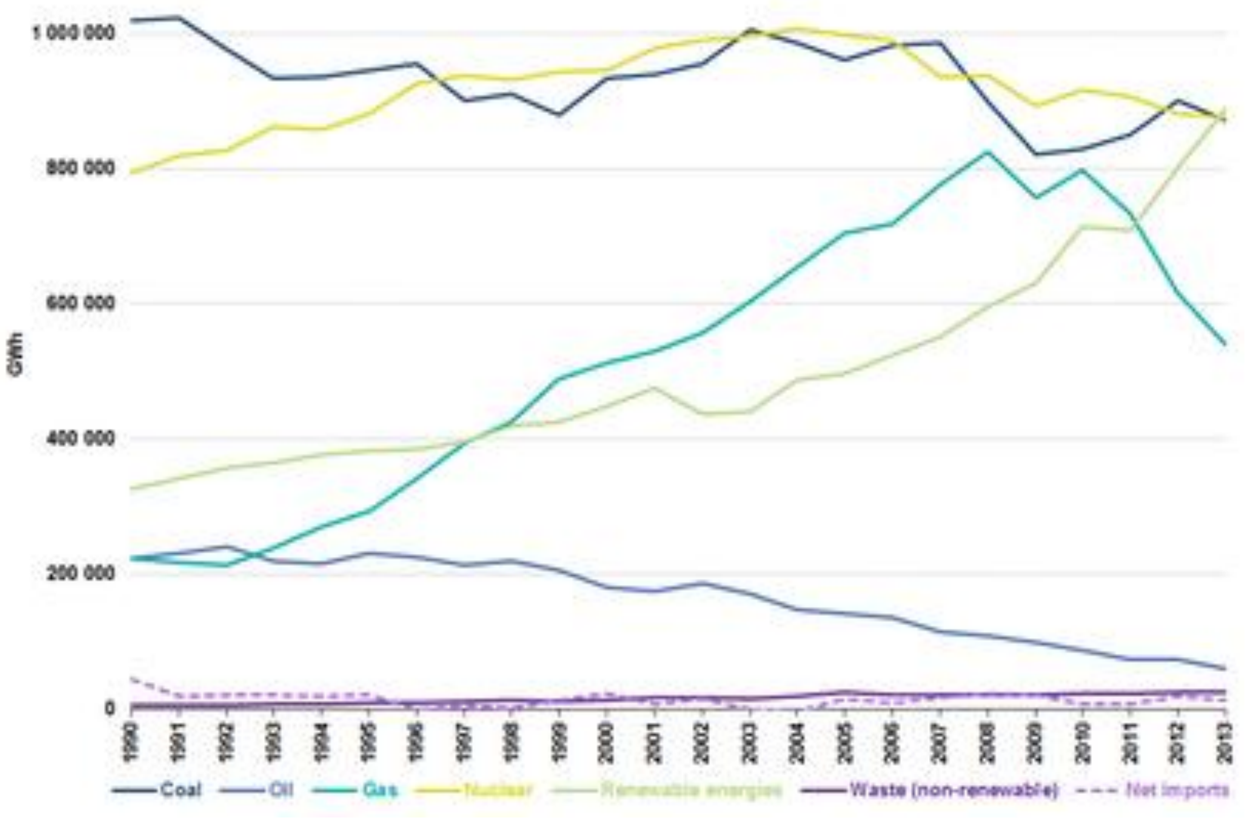
For example, whilst the UK was originally a leader in the design, development and deploying of Nuclear Power (fission type reactors) it was overtaken in the late 1970's principally by France in Europe when Nuclear fell out of favour in the UK resulting in the virtual loss of that skill and supply base – whilst France moved comprehensively into the Nuclear field now with around 80% of its electrical generation from Nuclear stations. This has meant that today France is a technological leader globally, whereas the UK was 30 years ago.

Oil, though, is still the key driver in the EU energy market with the EU bloc as of 2014 according to the EU Energy Strategy report in 2007 the EU imported 82% of its oil, 57% of its natural gas and 97% of its Uranium ore; this is a large outflow of capital that is unsustainable.

To this end, in a bid to reduce the reliance on oil the EU has made tremendous strides in increasing the renewables and moving from fossil fuels; Figure 18 shows the fuel changes from 1990 to 2013

URL:

http://ec.europa.eu/eurostat/statisticsexplained/index.php/File:Gross_electricity_generation_by_fuel,_GWh,_EU-28,_1990-2013.png

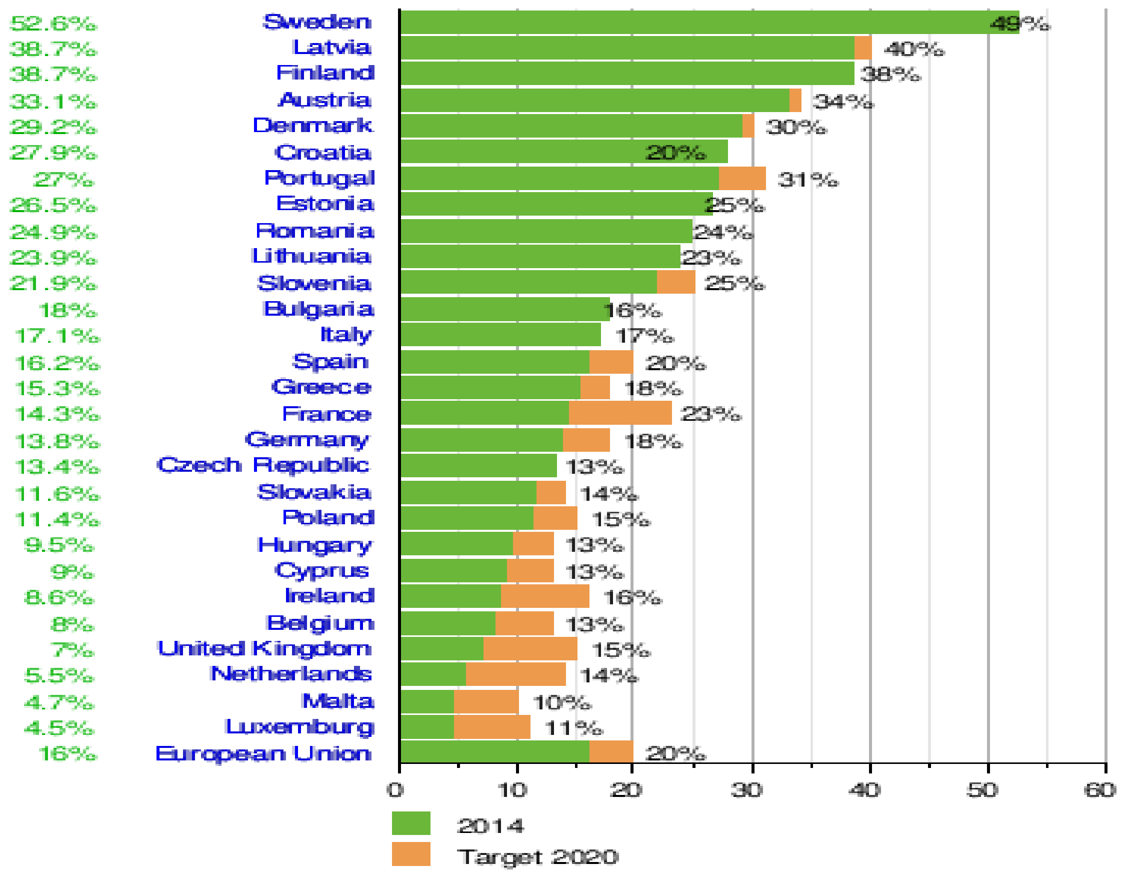


Source: http://ec.europa.eu/eurostat/statisticsexplained/index.php/File:Gross_electricity_generation_by_fuel,_GWh,_EU-28,_1990-2013.png

as of November 2016

Figure 18: Eurostat EU Fuel mix 1990 to 2013 – Fuel Type vs GWh Generated

This overall shift away from fossil fuels to renewables is not balanced across the 28 states with some states having elevated levels of Renewable content such as Sweden whilst the UK lags far behind this imbalance can be seen Figure 19 which gives a comparison of renewable energy generation by EU state as of 2014.



Source: URL [Share of renewables in energy consumption in the EU rose further to 16% in 2014](#).

Figure 19: Share of renewable energies by energy consumption in by EU countries in 2014 (Eurostat News Release, 2016)

To allow the UK to meet its obligations drastic action must be taken to lift its levels of renewable energy, as shown in figure 19 above. By 2014 the UKs approach had targeted electrical generation, as previously discussed, whereby subsidies were given to various electrical generation technologies to drive their take-up by both commercial and residential users. This has, to a degree, worked but it has also left the far larger element of the UK energy mix still to be worked on. This being the heat generation sector, which is a far larger sector than electrical generation, and requires a different intervention approach to help drive change.

It has also been viewed that whilst new electrical generation plants have to be procured to replace the aging generation stock – heat generation is more of a seismic shift away from buildings with individual boiler systems to more unified network solutions which will require a physiological change by operators and also by investors. This need to drive a change from just modernising electrical generation to heat led to the 2012 Heat Strategy as discussed in section 1.1. This now the key driver to the kick start the move to Decentralised Energy generation whether for primary heat production or as useable by product from electrical generation. The heat then being fed into newly built District Heat Network systems, such an expansion will be difficult due facilitate due to:

1. A lack of a UK based supply chain,
2. A lack of training provision in DHN skills,
3. A lack of understanding of the financial dynamics of DHN operation such as baseline costs and return rates (IRR and ROI) to release conventional private sector investment.

4.2 - UK sectorial changes: Industrial to Finance and Service and back again

The UK has undergone a prolonged change in its commercial base since the late 1960s – until this time from the end of World War II the UK can be said to have continued with an Industrial biased commerce system based on large factory plants with large semi-skilled workforces.

This renewal and replacement of Industrial assets did not however occur in the UK, which resulted in a situation whereby during the late 1960s and early 1970s the manufacturing base was operating with high levels of aged equipment, high levels of semi-skilled workers and low levels of investment. This therefore saw the market becoming less competitive in terms of productivity, adaptability, flexibility and attractiveness for higher skilled workers and industries. There was also a counter in that the politics of the day whether being driven by Conservative or Labour ideology were pushing a larger Government led public sector economy, in which the service and retail areas in the private sectors where also growing. This lead to a situation that manufacturing, and its supply chain base were not resilient when the effects of the early 1970s oil crisis worked its way into the economy.

By the early 1980s manufacturing and heavy industry were in major decline across the bulk of the UK; but particularly in the Midlands, North West and North East, with Central Government holding to a

Thatcherite policy of giving no to little financial public support as had been pursued in the 1970s. This therefore resulted in large traditional industries aiming to achieve higher levels of efficiency to reach a level playing field with upcoming competitors overseas, which at this time would be Germany and Japan. Contrary to this, the other option for the UK was to wither and take the increased socio-economic effects brought by prominent levels of unemployment by utilising the growing revenues into Treasury, from the North Sea Oil growth, to cover the costs of social care and the benefits system.

Consequently, there was also no economic regeneration policy activity from Central Government. During the mid-1980s, in reaction to periods of social unrest, an effort towards regenerating specific areas where large industry sectors had collapsed was brought about by the "Garden Festival" interventions. These effects were targeted towards turning estate assets from being un-usable and often contaminated sites, into useable future proof sites for redevelopment, with an interim stage as a socially attractive Garden Festival Site. However, these had no real lasting economic regeneration effect as the festivals were transitory lasting for a year at a time with little follow on plan.

The key economic change during the 1980s and 1990s saw a politically motivated move away from an industrial base, balancing this degrading of industrial capacity was the explosion in financial services helped by the deregulatory changes brought about by what was known as "the big bang" in the City of London financial districts.

Conservative Focus on Developing Financial Service Sector in the 1980's and 1990's

For the UK, the Financial "Big Bang" became one of the cornerstones of Prime Minister Thatcher's government's reform programmes. Before these reforms, the once-dominant financial institutions of the City of London were failing to compete with foreign banking. While London was still a global centre of finance, it was being surpassed by Manhattan in New York, and was in danger of falling further behind. Japanese finance centres were at this time starting to enter a slow down due to the deflationary effects in play in the Japanese market place and the Chinese effect had not yet taken off following the market changes of Deng Xiaoping.

Darby and Lothian (1983) in their paper reviewing economic policy under Margaret Thatcher's government claimed that the two problems behind the decline of London banking were over-regulation and the dominance of elitist old boy networks and that the solution lay in the free market doctrines of competition, reduction in regulation and also meritocracy.

This resulted in the policy of deregulation developed in 1983 and enacted in 1986 known as "Big Bang", is used in reference to the sudden deregulation of financial markets, including abolition of fixed commission charges and of the distinction between the stockjobbers and stockbrokers on the London Stock Exchange and change from the open trading floor (verbal floor) to electronic, screen-based trading, effected by Margaret Thatcher in 1986.

This policy of deregulation or "Big Bang" was the result of an agreement in 1983 by the Thatcher government and the London Stock Exchange to settle a wide-ranging anti-trust case that had been initiated during the previous Labour government under Prime Minister James Callaghan (by the Office of Fair Trading) against the London Stock Exchange under the Restrictive Trade Practices Act 1956.

Typical of these restrictive practices includes the London Stock Exchange's rules establishing fixed minimum commissions, the 'single capacity' rule has enforced a separation between brokers acting as agents for their clients on commission and jobbers who made the markets and theoretically provided liquidity by holding lines of stocks and shares on their books. There is also the requirement that both brokers and jobbers should be independent and not part of any wider financial group, and the stock exchange's exclusion of all foreigners from stock exchange membership.

Margaret Thatcher's government claimed that the two problems behind the decline of London banking were over-regulation and the dominance of elitist old boy networks and that the solution lay in the application of free market doctrines.

In reality there was little government regulation introduced in 1986 – the rules were those of private companies and associations, and people were free to trade on rival exchanges or to trade "off exchange". Treating the voluntary rules of private companies and associations as if they were the same thing as government "regulations" is a basic error. The rules of conduct of the private companies and associations of "The City" pre "Big Bang" had evolved from the results of experience of settlement of anti-trust cases which resulted in targeted government legislation.

The effects of deregulation and the introduction of new computer-based trading led to a dramatic turnaround within a very short time measured in a few months, with the City of London's place as the "global" financial capital decisively strengthened. The resulting boom resulted in the relocation of institutions into new developments in the nearby Isle of Dogs area, particularly that of Canary Wharf.

Whilst the "Big Bang" deregulation eased stock market transactions there is a now debate in the UK about how far it created the conditions that led eventually to the 2008–2009 global financial crisis and in 2010, Nigel Lawson, Thatcher's Chancellor at the time, appeared on the radio programme Analysis to discuss the banking reform. He explained that the 2008–2009 global financial crisis was an unintended consequence of the "Big Bang" (A price worth paying? – Analysis. 1 February 2010. BBC Radio 4. Retrieved 12 August 2012). He said that UK investment banks – the merchant banks, previously very cautious with what was their own money before the Big Bang, had merged with high street banks putting depositors' savings at risk, and so high risk previously an anathema became the norm also and crucially investments were only normally made if there was a quick return and a high rate of return.

This change to high risk, quick return and high rates of return as a private sector investment model is being discussed here as it is crucial to the present situation in that the move to Decentralised Energy which the Government needs to happen requires the financial world that existed pre-Big Bang; in that Merchant Banks were prepared to take on lower rates of return related to major infrastructure rather than what the City of London offers today.

Therefore, with the economic downturn compounding on ingrained industrial decline in many UK regions combined with a planned UK Government move to financial service led economic base, it needs to promote long term return on investment energy projects to the private sector. This has been approached by i) the establishment of the Green Investment Bank and ii) promoting the conventional city led investment models by creating financial support mechanisms such the Feed in Tariffs, FiT's and Renewable Obligation Certificates, ROC's, to give additional payments for low carbon electrical generation. Both these models though have an issue that power generation investment has long periods for returns, which goes against that private markets requirement for short term higher rated return models.

This is a financial conundrum for the UK Government as it has no appetite or ability to finance infrastructure debt that is required so it needs to free up private sector investment– therefore it needs to demonstrate that Decentralised Energy DHN's are good investments which whilst having potentially low rates of return will have sustainable returns for many years. So, Decentralised Energy deployment is needed as part of the UK's need:

1. to replace its power generation capacity,
2. to alter the way power is supplied with Smart network investment,
3. align skills training in HE & FE to Decentralised Energy and Smart network technology,
4. kick starting supply change diversification into innovative micro power generation,
5. supply chain development to support UK projects and then to move into technology hardware and service export.

Point 5 is key here in rebalancing of UK economy away from being debt driven retail and financial services need for trade deficit reduction by export growth.

Considering the energy investments around decentralised energy and Smart energy networks it is crucial that pump priming of supply chains to diversify into the market place for both UK activity and also for export potential is absolutely crucial.

4.3 - Local Enterprise Partnerships

4.3.1 - Move from RDA to LEP

Stoke & Staffordshire LEP Regeneration approach and objectives

Until 2010 regional economic support was through the Regional Development Agency's with 9 covering the NUTS Nomenclature of Territorial Units for Statistics (NUTS) Level 1 areas of the United Kingdom as below in Figure 20: RDA zones of the UK as up to 2011:

North West:	**Northwest Regional Development Agency**
North East:	**One North East (ONE)**
Yorkshire and the Humber:	**Yorkshire Forward**
East Midlands:	**East Midlands Development Agency (EMDA)**
West Midlands:	**Advantage West Midlands (AWM)**
East of England:	**East of England Development Agency (EEDA)**
London:	**London**
South East:	**South East England Development Agency (SEEDA)**
South West:	**South West of England Regional Development Agency**

Figure 20: UK RDA Zones as up until 2011

The Coalition Government of 2010 to 2015 decided to wind up the RDA model and instigated a smaller more local model through which to support economic regeneration which was primarily to have a Private sector lead over the RDA model of Public sector lead.

The RDA's were then viewed as a risk and decision model that showed a lack of activity, action and return on the funds that had been invested. This move from RDAs to LEPs was to realise the devolution of power to more localised business driven areas than the RDA represented. This was aligned with the

Lord Heseltine "No Stone Unturned" plan to stimulate growth in local areas (Heseltine, 2012) on driving dynamic economic regeneration.

The creation of the LEP structure across England and Wales by the new Coalition Government of 2010 to replace the previous Labour Government Regional Development Agency was meant to allow a more "localism" focused view on what would drive economic growth - with the individual LEP's not being subject to a London specified model. The local partnership of public sector entities – Authorities, Universities, NGOs would work with the "local" business community to develop growth strategies that are best suited to their circumstances rather than be dictated to by Central Government. This was one of the first steps resulting from the Lord Heseltine study "No Stone Unturned" which advocates major devolution of power and control of financial matters from London into the regions to be driven by the local agenda. The key part of this devolution was that the business community would partner with the public sector and would identify and drive economic growth.

The Lord Heseltine "No Stone Unturned – in pursuit of growth" document (BIS/12/1214) set out a wide ranging and comprehensive economic plan to improve the UK's ability to create wealth or increase its ratio of GVA. Whilst the report was essentially commissioned by Prime Minister Cameron and Chancellor Osborne, it was independently researched and developed which was against the normal practise in Whitehall, as if implemented even in part would see a major restructuring of power and the control of finances away from London to the local economies. Hence it has received considerable resistance to being fully deployed, as observed by the author, forming the perspective of being a LEP Board member during the period November 2012 to January 2017. Its deployment has been undertaken in a much-controlled form, whilst hesitant steps have curtailed the speed and potential for economic regeneration. The Heseltine report makes 89 recommendations which fundamentally aim to:

- Inject stability in the economy – locally stability giving national stability
- Create the conditions for growth – local power on decision making and financial control

- Maximise the performance of the UK
- Unleash the potential of local economies and leaders to enable every part of the UK economy to raise its game.

This was a planned move by London to move away from centrally driven economic regeneration agenda which was likely not to be aligned with differing regions needs and issues – it was to let local commerce drive the type of agenda it wanted.

In the 2012 Autumn statement the Government provided its response to Lord Heseltine's proposals in "A new partnership for growth" this focused on local economic growth through key developments:

- *Creating a single Local Growth Fund allocated through a process of negotiation and using competitive tension to strengthen incentives on LEP's and their partners to generate growth,*
- *Empowering Local Enterprise Partnerships (LEPs) and devolution of some central funding streams into a single pot from 2015 onwards,*
- *Asking LEPs to develop new strategic multi-year plans for local growth, which will be the basis on which the Government negotiates deals with each LEP for levers, resources and the flexibility over them; and*
- *Streamlining the management of EU Structural and Investment Funds in England and aligning priorities on the basis of the plans led by LEPs,*
- *Central Government will provide a further £350 million for the RGF, of which £100 million is being contributed from existing budgets,*
- *Combined Local Authorities; government will support local authorities who wish to create a combined authority or collaborations, including ensuring the existing legislation is fit for purpose,*
- *A package of regulatory changes to improve how regulations that affect businesses of all kinds are enforced; in addition, government will operate a one-in two-out rule on*

regulation from January 2013.

In March 2013 HM Treasury and the Department of Business Innovation and Skills (BIS) published the government's official review and response (DECC, Cm8587) to the Heseltine review in which it accepted either in full, or in part, 81 of Lord Heseltine's 89 recommendations.

The LEPs initially, unlike the RDA's they replaced, had no budgets or finance base – this can be seen as an easy tactic by Treasury in London to "claw" back some £4-5 Billion from the killed off RDA budgets back into central Government control at a time of financial restraint and deficit reduction.

Therefore, when LEP's, became established, they began to develop their regeneration programmes – their "ask" into central government would be essentially a give us "this" and we will deliver "that". The "this" – the ask would be finance packages that were either EU linked or unique UK cash. The "that" being an economic measure normally in terms of job creation or GVA (Gross Value Add) increase. As an example of this the Stoke and Staffordshire LEP in 2011, proposed to Central Government it would create by 2020 some 50,000 new jobs, and a 50% in GVA. In regard to these targets by mid-2016 the SSLEP had funded programmes and strategies in place resulting in it having created 23,000 jobs and a 22% increase in GVA as measured by Treasury in its 2016 review of LEP performance– lifting the overall value of the local economy to be higher ranked nationally. To achieve this, a range of economic regeneration proposals were prepared around a key focus termed as "Powerhouse Central" which developed into a City Deal submission in 2013 Stoke-on-Trent and Staffordshire LEP City Deal. 2014).

The City Deal approach was developed by the Cameron Government in 2012 to badge major economic regeneration investment packages into LEPs and associated City areas.

For the Stoke and Staffordshire LEP the original Powerhouse Central City Deal submission had four key focus points:

- Lift and enhance skills and training – this would be to also drive ambition, attitude and entrepreneurship. The skills focus especially on STEM subjects won immediate funding support from Central Government for as it was aligned with National Policy Developments,
- Support infrastructure and business site developments – this was based around 22 already identified locations in the Stoke and Staffordshire LEP region – again this won support from Central Government as it was aligned with National Policy Developments,
- Establishment of Advanced Materials development centre – this was to build on areas materials processing specialism – it was driven by the areas Universities and Ceram / Lucideon; this has now moved forward with the launch of the AMRICC – Applied Material Research, Industrialisation and Commercialisation Centre to be based in the also newly announced Ceramic Valley Enterprise Zone,
- The main focus was to utilise the area's inherent unconventional energy assets as provided by Deep Geothermal, Coal Bed Methane, Mine Water Heat, and Waste Industrial Heat; and to deploy Smart Energy Network grid technologies. Aligned with the potential to access the energy assets the opportunity would come into being to develop a supply chain base around these new Decentralised Energy technologies – as these do not exist in an appropriate size in the UK to provide the accelerated growth as required to overcome the upcoming UK power generation and grid shortfalls.

This last point, in regard to energy in the form of decentralised energy, District Heat Networks and Smart Network developments were viewed by Whitehall as a unique proposition by the Stoke-on-Trent and Staffordshire LEP when compared to the other 38 LEP submissions for funding growth programmes.

Thirty-Nine Local Enterprise Partnerships (LEPs) came into being replacing the 9 RDAs. These 39 LEPs across England mainly take up an historical representation of established County and Urban areas as this links with long established political ward boundaries. There are a few exceptions where local agreements have seen multi county areas combined, such as in the South East LEP which operates both north and south of the Thames east of London. The 39 LEPs are shown in Figure 21 as from the Government Department BIS in 2012.

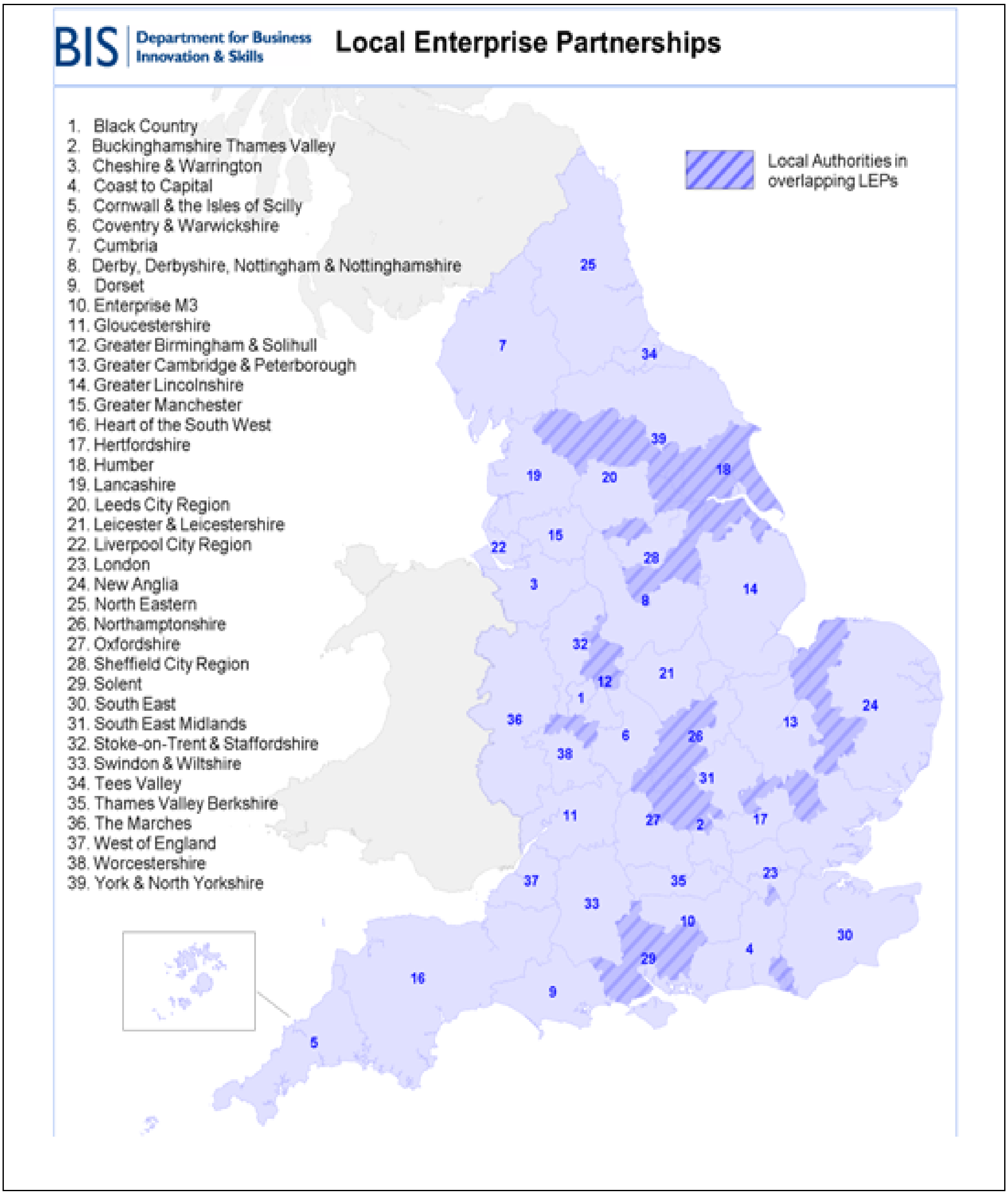


Figure 21: UK LEP Structure as of 2012 (Department of BIS, 2012)

Within the old RDA region of Advantage West Midlands (AWM) six principal LEPs came into being covering the West Midlands, these being:

1 Black Country LEP (BIS Ref 1)

2 Coventry and Warwickshire LEP (BIS Ref 6)

3 Greater Birmingham & Solihull LEP (BIS Ref 12)

4 Stoke and Staffordshire LEP (BIS Ref 32)

5 The Marches LEP (BIS Ref 36)

6 Worcestershire LEP (BIS Ref 38)

As part of this six the Stoke and Staffordshire LEP (SSLEP) (BIS Ref 32) came into being covering as its title suggests the Unitary Authority of the City of Stoke-on-Trent and the County of Staffordshire, the County encompassing the Tier level of Authorities below NUTS Level 1 known as LAU 1 or Districts. For the Stoke and Staffordshire LEP these Districts being:

- Stafford Borough Council
- Newcastle-under-Lyme Borough Council
- Staffordshire Moorlands District Council
- Tamworth Borough Council
- Lichfield District Council
- Cannock Chase Council
- South Staffordshire Council

Therefore, it can be seen that there is a spread of area types from Industrial through urban (peri-urban) to agricultural – so many differing public drivers and needs.

Other public-sector entities are represented in the board structure such as education at a further and higher education level, this enables the tertiary colleges and universities (Keele University and Staffordshire University) to be engaged in the policy and programme development of the SSLEP. Also on the LEP board, as a counter to the public sector, are directors from the private sector from local large business players and SMEs, these were recruited by advertising positions with interview sessions from out of the SSLEP business community.

Up until late in 2014 the main governance model for the Stoke and Staffordshire LEP was through a Board of Directors with 10 private sectors “Business” members and 10 counter seats of which 9 were taken by the LEP Local Authorities and one is co shared between Keele University and Staffordshire University. This SSLEP model of governance was viewed as acceptable with the Whitehall DCLG LEP model for UK wide LEPs.

Prior to the City Deal being awarded to the SSLEP in 2015, DCLG and the Cabinet Office specified that one of the conditions of the financial deal was that the LEP governance model needed to evolve and have an aspect of a legalised delivery executive body, above the full board level. This came into being in mid-2015 and satisfied DCLG and the Cabinet Office.

The SSLEP works to bring all the stakeholders within its local area together – both from the private and public sector to drive local economic growth. The view being that the private sector has a working insight, and a focus on where opportunities are and what the current barriers are preventing growth. This is articulated in the Stoke and Staffordshire LEP’s Annual Report 2016 Page 5 as “our business-led partnership of private, public and academic partners aims to ensure that local expertise and experience are instrumental in supporting local growth”.

This is a subjective area as there is no direct requirement on LEPs to consider energy in their focus areas to gain economic growth. This is primarily since LEPs determine their own priorities and develop them into a competitive bid approach into Central Government. Therefore, a LEP can bring an element of energy into their agenda if it so wishes – a number do but for varying reasons not because it is a mandated requirement.

Therefore, driven by the set of comparison measures in Figure 24 & 25 the SSLEP has set itself an ambitious target when you combine a 50% increase in GVA with a Powerhouse Central City Deal commitment for 20,000 new jobs these being a substantial part of the 50,000 new jobs promised by the SSLEP in 2011. To gain the 50% GVA increase these 20,000 new jobs must be in the main be in far higher levels of value add such as professional services, engineering design consultancy, financial and legal service provision. If in manufacturing and industry the output must be of a substantial higher value.

To gain such an increase this must be through new supply chains being established which are possible in the decentralised energy sector. Such gains cannot be won just by undertaking the delivery of the project itself it must be through engaging in the local business community to get the pound spend to stay local but also aid them to prepare for the bigger opportunity of UK wide decentralised energy DHN type projects.

The key question of this research, which is to be considered, is whether the take up and move towards decentralised energy act as a driver for substantial economic regeneration, relating to this the Stoke and Staffordshire LEP (SSLEP) is the main focus of analysis. This is due to the driving discussions which the SSLEP has had with central government for programme support in its City Deal, ERDF, ESIF, RGF, and LDF applications relating to the Powerhouse Central proposal.

The SSLEP Powerhouse Central proposal is not purely about energy generation from local assets – it is this and more with complementary focuses on improving skills, infrastructure site and the establishment of the AMRICC – the Applied Material Research, Industrialisation and Commercialisation Centre.

The SSLEP energy focus is to develop the Stoke-on-Trent District Heat Network and the synergetic Keele University SEND, Smart Energy Network Demonstrator. Whilst these are energy “hardware” projects in the main they also bring with them the opportunity of local and regional supply chain opportunity into participating in their delivery. This is seen as an economic growth opportunity by the SSLEP and at the London Whitehall Departments involved with driving energy project delivery.

4.3.2 - UK Issues – LEP/ LA / UK Government and the Energy Agenda

Consideration needs to be given for the specific UK issues that are both influencing and hindering the deployment of Decentralised Energy, in terms of the technology rollout and the potential for supply chain diversification. A review of the unconventional energy opportunities to drive the increase of sector capacity, skills levels, innovation and investment options.

The UK has specific issues relating to an overriding need to replace its ageing electrical power generation capacity and modernise the national grid infrastructure. Aspects of this major infrastructure investment in 2014 were broken down in a DECC Ministerial paper “Delivering the UK Energy Investment, July 2014”, this paper gives a breakdown of spend profiles for differing energy sectors.

In the paper forward by the Energy Minister in 2014 Ed Davey at the time a view that urgent action was required to as it was put “keep the lights on, as a fifth of our existing power stations were scheduled to close by 2020 because they were old, inefficient or polluting” which would be a major national investment programme, and it went on further comment on the fact that a straight unit for unit replacement approach would not be sufficient – so the investment challenge was even greater to satisfy the legal need to meet climate change targets as detailed in the Climate Change Act of 2008 and the associated international obligations relating to the Kyoto Protocol and the Doha Amendment sitting under the auspices of the UNFCCC (United Nations Framework Convention on Climate Change). So, there is in the Energy Investment document a UK Government acceptance of the ley aspects that make up the UK “Energy Trilemma” of Cost vs Security vs Carbon.

This is seen by observation of the Stoke and Staffordshire LEP that there is clash of national versus local policy needs and drivers, that there is created a double trilemma situation as in Figure 22, with a balance point even more difficult and constrained to achieve.

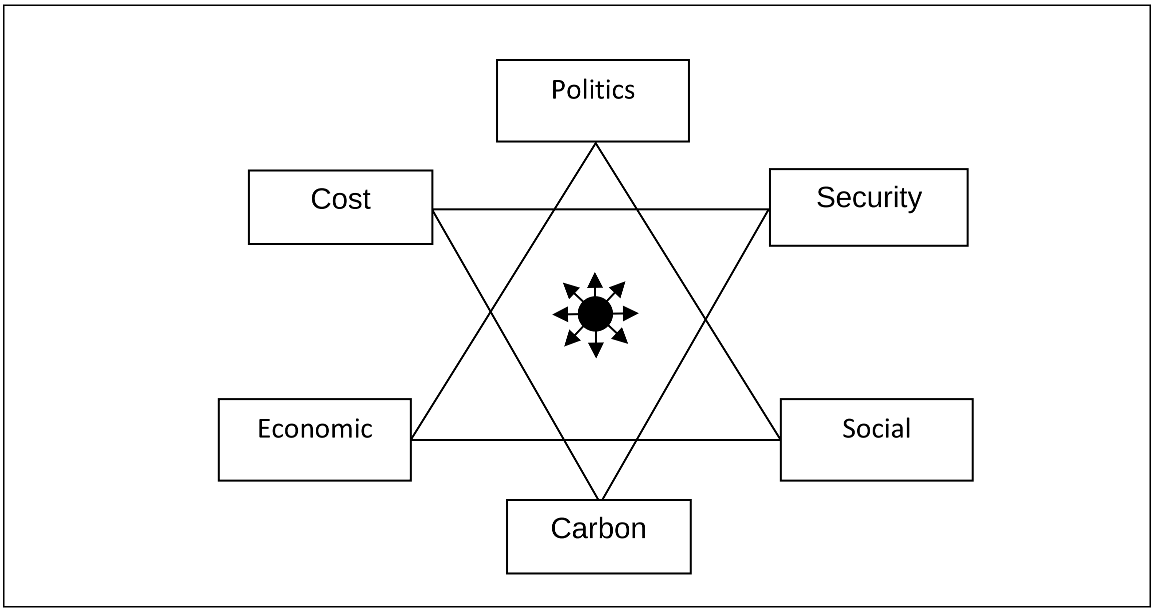


Figure 22: The Double Energy Trilemma

Reference is made to associated problems that add complications to achieving this balance regarding the slow speed of innovation and technological change in the energy sector; linked with an acceptance of a long-established market failure of planning for generation replacement and market capacity coverage.

The UK Government portrayed both in its Treasury Office 2013 plan (Treasury Office, 2013), and in the DECC paper on needed energy investment levels in 2014 (DECC, 2014), the level of required investment plans for present and future activities. The papers also defined policy drivers to meet the needs of the Energy Trilemma, to kick start innovation in the supply chain and, to set legal obligations on the market to provide operational and reserve generation capacity.

This has led to a doubling of annual investment in renewable energy since 2010 to a level in 2013 of almost £8 billion with further higher levels of investment planned for. There has been facilitation activity to combat the key challenge of prompting private sector investment to be made in emerging low carbon technologies that are crucial to electrical generation in the coming period of 2020 to 2050. The investment target areas are both for major infrastructure such as new nuclear power stations at Hinkley Point, Wylfa in Anglesey, Oldbury in Gloucestershire, Moorside in Cumbria – the level of investment is viewed in the paper as around £46 Billion and as creating some 21,000 jobs in the construction period.

Aligned with major plant build and operation is to develop the Carbon Capture and Storage, CCS, technology to be applied to existing systems. An example of CCS developments is as by John Goodwin International based in Stoke-on-Trent with their work with Toshiba and NetPower on the high pressure and high temperature CO2 Turbine that brings the benefit of a CCS technology and produces power at the same time in the Allam Cycle with the pilot plant development to be built in Texas USA in late 2016 early 2017.

The Allam Cycle can operate with coal and natural gas fuels and enables due to the operating temperature and pressure for both H_2O and CO_2 to be in co-exist as liquids – where the CO_2 can act as the driving fluid for the turbine as shown in Figure 23. John Goodwin International Ltd who are specialists in metal alloy casting are working on super Nickel alloy developments with funding from BIS, that have low creep and high fatigue resistance at the temperatures and pressures that an Allam Cycle turbine requires.

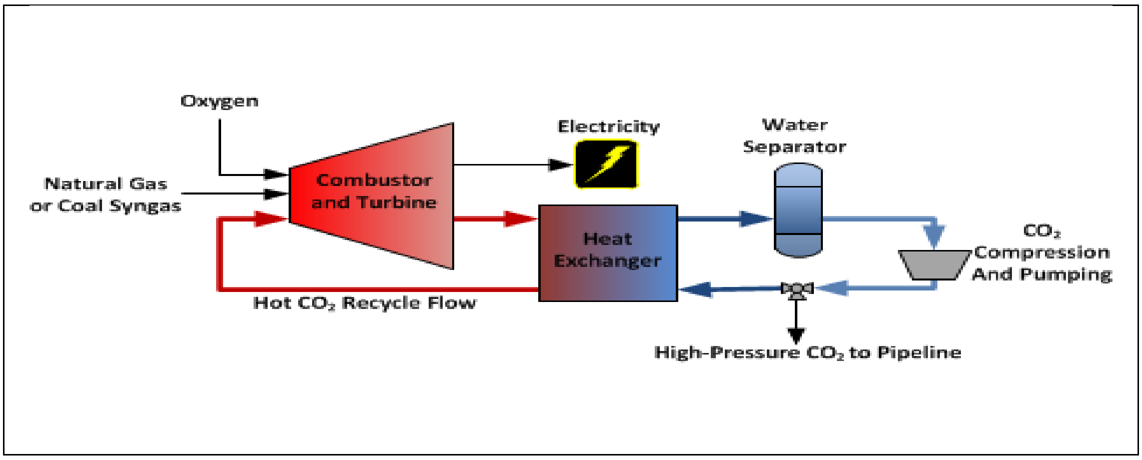


Figure 23: Allam Cycle – High Pressure / High Temperature CO2 Turbine (NetPower)

The balance of this major infrastructure with build of new multi Gigawatt generation plant and also including major replacement of the ageing national grid distribution network is the move to Decentralised Energy which will allow localised smart networks and megawatt sized generation plant for both electrical generation and also for localised heat distribution.

Investment in Decentralised Energy deployment will target the major issue of fuel security which affects the UK's ability to operate commercially, in particular regard to the provision of heat. The UK Energy Investment document outlines that the production of heat accounts for 20% of energy use – with 60% of heating demand relating to natural gas use. Natural gas from the 1960's and 1970's offshore gas fields is set to rundown in the next 10 years with the UK already moving to be a nett importer of natural gas unless new reserves or resources are found and developed. This predicates the move to exploit Shale Gas as is being pursued in the development of the Government's Oil and Gas Authority (OGA) – the UK's oil and gas regulator established in April 2015. This is the result of the Government implementing recommendations from the Wood Review with the aim of maximising economic recovery of offshore and onshore oil and gas resources.

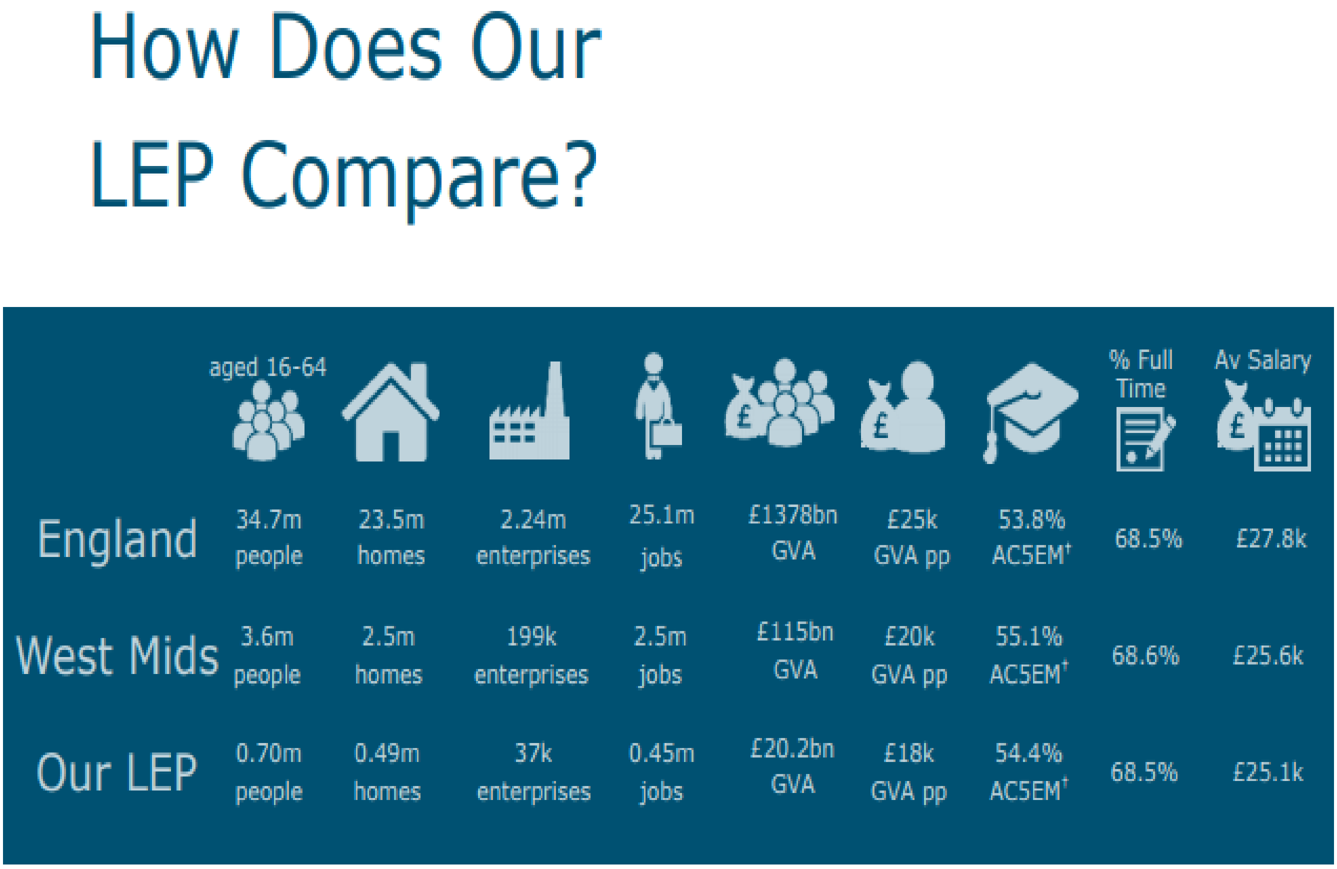
Development of onshore Shale gas related to the Bowland basin and Coal Bed Methane in unworked aspects of UK coalfields is detailed in Appendix 2. Onshore shale gas and oil is viewed by the OGA to be an annual investment level of some £3.7 Billion and support some 60,000 jobs in the supply chain.

The key point of shale and CBM related development is that the gas can be utilised in existing plant both in large CHP, Combined Heat Plant / CCGT, Combined Cycle Gas Turbine and in commercial and residential gas boiler systems, so minimising infrastructure spend as we would continue using what we already have.

4.3.3 - Stoke & Staffordshire LEP – Decentralised Energy Focus

As discussed in the Literature Review section the LEPS were created by Central Government to replace the RDA structure across England; Wales and Scotland due to their devolved status have their own models of partnership in place which are not part of this research boundary.

This for the SSLEP means there are differing needs, aims and aspirations when considering economic regeneration and the elements that would make-up its approach and policy. What was key to establishing this is that when in discussions in London a common set of parameters or KPI's that formed a language set used across all LEP's – these could then be used as the justification for policy focuses. This set of measures, as in Figure 24 below gives the variance to the National and Regional West Midland position, for the SSLEP as shown in the AGM Annual Report for 2016 (p.6).



How Does Our LEP Compare?

	aged 16-64							% Full Time	Av Salary
England	34.7m people	23.5m homes	2.24m enterprises	25.1m jobs	£1378bn GVA	£25k GVA pp	53.8% AC5EM†	68.5%	£27.8k
West Mids	3.6m people	2.5m homes	199k enterprises	2.5m jobs	£115bn GVA	£20k GVA pp	55.1% AC5EM†	68.6%	£25.6k
Our LEP	0.70m people	0.49m homes	37k enterprises	0.45m jobs	£20.2bn GVA	£18k GVA pp	54.4% AC5EM†	68.5%	£25.1k

Figure 24: SSLEP Comparison of Key Measures to National and the West Midlands (SSLEP AGM Annual Report, 2016)

When then considering how these measures vary across the SSLEP region rural vs city areas, and how the SSLEP fits in with connectivity with the nearby major conurbations of Liverpool and Manchester to the North and Birmingham to the South the SSLEP is portrayed as in Figure 25 "A View of Our LEP" as from the SSLEP AGM Annual Report for 2016 (p.7).

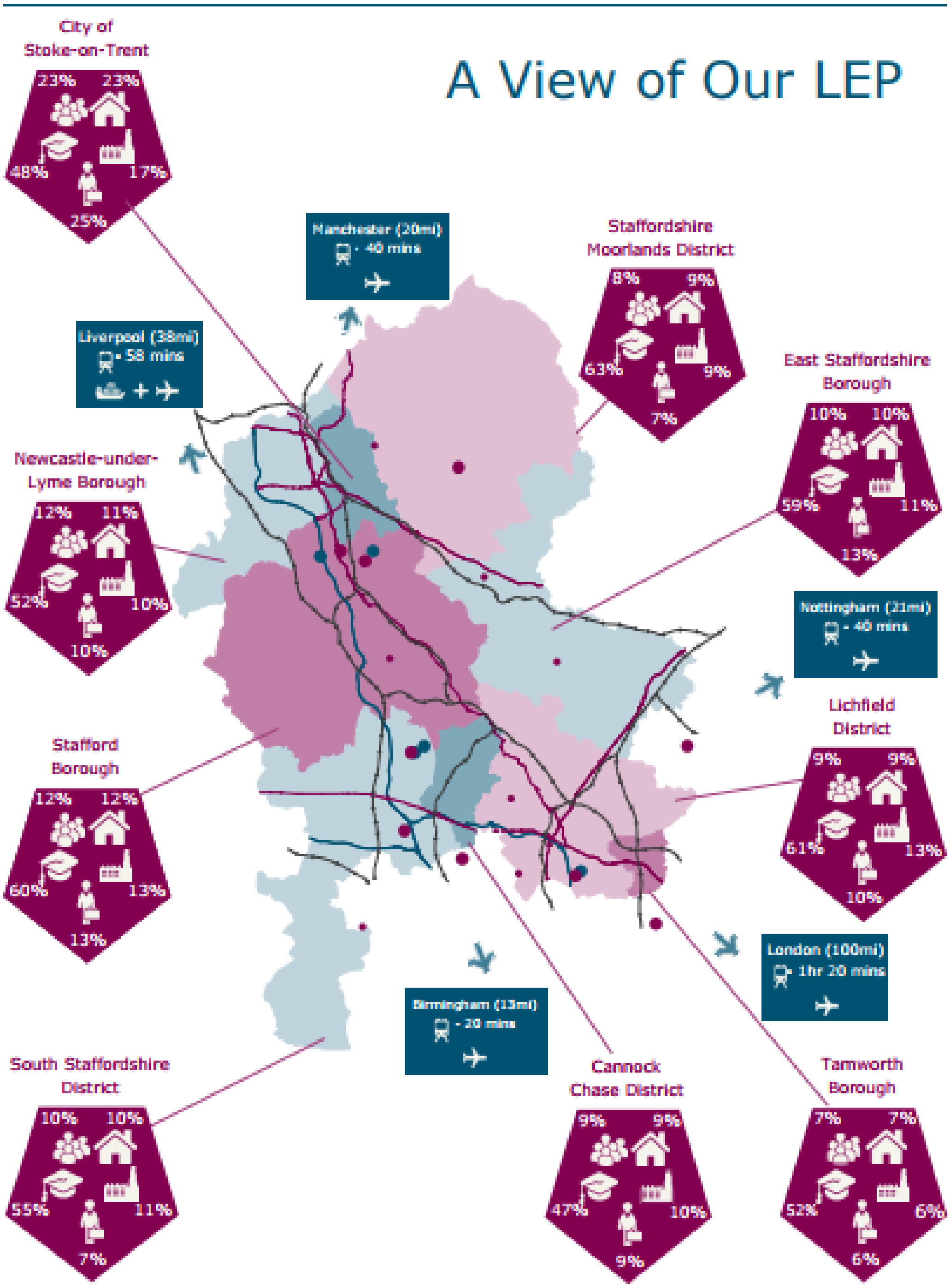


Figure 25: "A View of Our LEP": SSLEP AGM Annual Report for 2016 (SSLEP AGM Annual Report, 2016, p.7)

These key measures as shown in the two infographics in Figure 24 & 25 have highlighted two key elements that drive a need to set policy and enable supply chain diversification into new growing market areas as offered by central governments planned growth in decentralised Energy and DHNs; these are:

1. The disparity in the ratio of Enterprises in the SSLEP area compared to the national area per unit of population – with the SSLEP having some 22% less Enterprises / unit population.

   This is viewed as a lower level of "Entrepreneurship" ambition, aspiration and attitude in the SSLEP region – and a target for improving to be at and above the national average.

2. The GVA, (Gross Value Add per person employed) level, compared to National shows the SSELP to be some 39% below the average for England – this is basic sign of that whatever the level of employment it is mostly in low paid and low GDP adding activity. The SSLEP has a fundamental focus and target on this as announced back in 2011 in its earliest commitment to Central Government that it would lift the GVA by 50% in 10 years as well as creating 50,000 new jobs.

The low level of "Entrepreneurship" – which the SSLEP sees statistically as low rate of business start-ups, is a dynamic of a low business culture in the SSLEP area. To overcome this cultural state a focused programme targeting start-ups is required. To do this, potential entrepreneurs need to be identified and somehow given a "spark" of innovation. Such a spark could be promotional effort to get the message of the energy and other opportunities translated over.

This get over this constraint the SSLEP has established an opportunities communication strategy with a signposting "Growth Hub" service available to in and out of area businesses to use as gateway support to whom is best to talk to in regard to inward investment, training, funding etc.

4.3.2.1 - Opportunity – Stoke & Staffordshire LEP policy and governance

The overall aim of the SSLEP is driven by the government policy to gain economic leverage in the region(s) and locally by allowing the individual LEPs to utilise what it sees their own best assets and skill sets.

The SSLEP is driving forward its vision to make Stoke-on-Trent and Staffordshire "an economic powerhouse driven by the transformation of Stoke-on-Trent into a truly competitive and inspiring core city and by accelerated growth in our county corridors and urban centres" as stated in the SSLEP AGM Annual reports from 2014, 2015 and 2016.

This consistent vision has meant the SSLEP now has a fixed focus on driving the elements of its City Deal which sits behind its key policy to drive economic regeneration and achieve new job creation and increased GVA. The focus areas determine sub policy areas:

- Core City – drive rapid growth of Stoke-on-Trent city centre through improving its facilities and retail offer. In a Department of Communities and Local Government study on UK city centre retail offer in 2013 (DCLG Retail Study 2013) Stoke-on-Trent by consumer density ranks 13th in the UK but ranks only 64th in terms of retail offer.
  Improving the retail offer is crucial to supply chain and GVA growth – in that to attract higher level semi and full professional workers the local shopping area needs to be attractive to them and their families or they will not relocate.
- Sector Growth – to support innovation both by the private sector and with programmes at Keele and Staffordshire Universities – these two bodies have developed an innovation concord.
- Connected County – to develop the excellent connectivity offer with improved infrastructure at identified peri-urban and business sites. The policy is outlined in the County Council document "Leading for a Connected Staffordshire – Our Vision for 2014-18" the document can be found at URL website link at (URL: https://www.staffordshire.gov.uk/yourcouncil/strategicplan/Strategic-Plan-2014-18.pdf).
- Skilled Workforce – to develop a modern and flexible skills system which enables people to up-skill. This acts as an enabler to support supply chain diversification. This is

moving forward slowly but as discussed elsewhere in this research paper has implicit issues which sees that “new” market sectors are difficult to support with training prior to that new market coming into being as with Decentralised Energy.

- Competitive Urban Centres – building on the Core City development enhance the other towns across Staffordshire.

These focuses are to improve the lifestyle offer that the region can give to make it more attractive and inviting to new families – that is you and it is a simple basic “marketing” play that the region will not win the new skilled professional worker groups to come and relocate here if their families do not have a better lifestyle offer.

This approach of improving the lifestyle offer supports the focus on the priority business sectors which have regional policy drivers for targeted assistance:

- Applied Materials – supported by the launch of the AMRICC – Applied Materials Research, Innovation and Commercialisation Centre URL https://www.amricc.com/ as of November 2016, Materials research and development dovetails in excellently with other sector focus areas as listed here.
- Automotive & Aerospace – supporting the expansion of the already established Auto entities who are based in the North with JCB and in the South with the JLR engine plant which is now planning it phase 3 development for new hybrid power-plant plant to add to the already built engine plant and the being built gearbox plant. JCB is progressing with high growth with three new factories and an expansion of its JCB skills academy to add engineering degree courses to its already excellent Diploma and A level offer in Engineering and Business subjects. JCB are doing this through self-interest as it has been aware of a growing skills gap for a number of years and so started its own in-house A level and now to Degree level training capability.
- Agri-Tech – this is a growing area linked with UK and Global need for food security, it builds

on the large agricultural and forestry sector present in the SSLEP area predominantly in Staffordshire County Council. To a degree, it is an approach that mirrors the Agri-Tech concentration that is also being developed in the East of England in Lincolnshire where a large percentage of the UK's food processing and packing. At the University of Lincoln there has been established the National Centre for Food Manufacturing (see URL http://agrifoodtech.blogs.lincoln.ac.uk/ as of November 2016). The aim for the SSLEP is to be in partnership through a formal link of Harper Adams with this National Centre representing and covering the Agri-Tech interests in the Western part of England. The Agri-Tech sector offers great opportunities for export and overseas partnering particularly to China and in the Far East. This China element is part of the Mercian-Silkroad opportunity which is being developed at this time – which is based here in Staffordshire linking into Beijing and the key areas of Guangzhou, Tianjin and Chengdu. An example of this it the nearly complete direct rail link between China through Asia into Europe with a terminus in the UK at a new international rail hub at Barking, East London.

- Medical Technology – to develop and build on the already established Medical Technology hub based at Keele University on its Science Park where a number of International research leaders are based. The University in addition hosts the ISTM – Institute for Science Technology and Medicine which is also supported by the medical training link into the Primary Care Trust and the Royal Stoke University Hospital. (URL http://www.kusip.co.uk/73/healthcare-and-medical)
- Energy Generation – whilst the above sectors are not directly linked with the Energy field they demonstrate an approach to invigorate and support growth in high GVA supply chains – elements of which were already present put were prime to be expanded on. These sectors all demand a commitment to developing an enhanced highly skilled workforce which fits with the dynamic of developing the decentralised energy sector. A number of energy suppliers are established in the SSLEP region such as GE Solutions in

Stafford based at the old Alstom site, ABB Grid Solutions in Stone and Siemens Wind Power at Keele University. The Powerhouse Central deal expands on these business aspects by utilising the SOTCC DHN project and Keele University SEND – technology demonstrator as "bridging projects" to drive supply chain engagement and growth.

Figure 26 shows the Stoke and Staffordshire LEP integration and interlink of sectors with a central anchor based on skills:

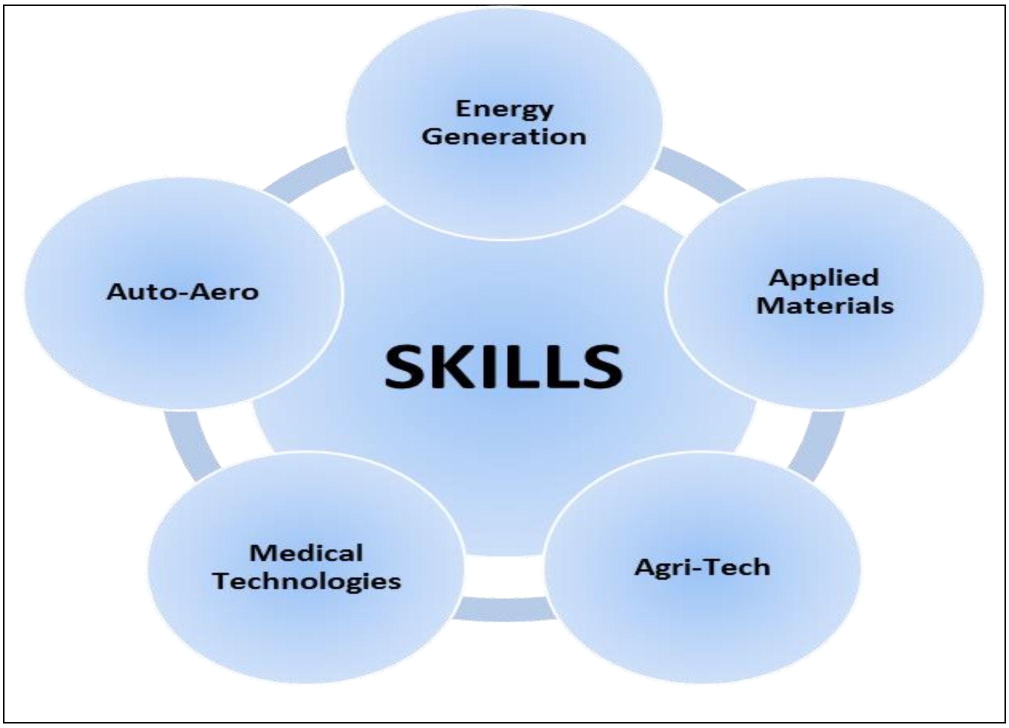


Figure 26: Stoke & Staffordshire LEP Target Sectors (LEP Annual Report, 2015)

There is one problem with this as there appears to be a gap in the bridge of projects in that whilst it is a focus, there is a mismatch of energy programmes of support activity into the supply chain regionally. As an example, in November 2015 BIS concluded the Growth Accelerator programme that was driving innovation and leadership development; whilst at the same time, the Manufacturing Advisory Service (MAS) programme was also stopped, with no direct immediate replacement model. Whilst there were problems with the programmes, to finish them with no model of replacement alienated business away from seeking government support, as business had no view of continuity. This was as observation made from the LEP Board position of the author in sessions with SSLEP businesses who expressed their disbelief and turned away from public funded programme support.

4.3.2.2 - Decentralised Energy: Workforce Skill Shortage

The HNDU (Heat Network Delivery Network) in BEIS accepts there is a serious skill shortage in deploying DHN projects, this is evident in that HNDU staff are undertaking stakeholder sessions around the UK in 2016 driving forward the issue of the skills gap and the required interaction of local authorities in driving forward District Heat Network projects (BEIS – DEPA Bridging the Gap presentation October 25th at GMCA). The skills issue is bluntly presented at these events with the fact that there are no specific college courses in this technology area in today's syllabus plans across the UK as of the September 2016.

The Principal of the South Staffordshire College Graham Morley, who sits on the SSLEP Board with the study observer, in December 2015 highlight the overall UK problem that is acting as a barrier here. Mr Morley is well informed and aware of the energy focus and upcoming projects – but he is bound by rules set by Whitehall in London that colleges cannot establish new courses where there is no job shortage.

So, we have a bizarre chicken and egg scenario – the colleges know there will be a need due to their activity on the LEP structure but cannot do anything about preparing for it with upskilling programmes as there is not a job shortage yet. When the projects start – jobs will be created – but then there is the time lag of at least one to two years whilst course programmes are created, certified by London and funding signed off.

This situation is known to the newly formed BEIS department through discussions with the HNDU – this is very worrying for them as it starts to make their overall DHN deployment plan slip through a lack of skills – at present they are trying to change their own rules and procedures to allow local colleges and training institutions to self-identify new markets with new job creation and then adapt or create the appropriate training. This is actually already too late for the Stoke-on-Trent DHN project as it starts going for procurement tendering in spring to summer 2017 as given by the Stoke Authority's

Energy Officer, Sebastien Danneels, at the DEPA event in with the GMCA on the 25th October with no training courses available until 2018-19 at the earliest.

Therefore, it is difficult for companies to approach the opportunity to participate in their delivery as there is a very small skill pool to recruit from. This small skill pool also is fully engaged in other DHN projects underway in the UK so to "headhunt" into this skill set group means offering higher pay and benefits packages.

4.3.2.3 - Decentralised Energy: Supply Chain Awareness

Decentralised Energy Supply Chain – Local and Regional Company Awareness of the project

As well as the skill shortage, there has been a degree of reluctance by the local authority, Stoke-on-Trent City Council, to undertake much promotion or headlining of the upcoming DHN project in the City. This in the main has been due to political issues with a change within the administration from Labour control that initially developed the DHN concept to an Independent & Conservative led council that initially questioned the viability of pursuing the project. At this time, the DHN project had already been signed off as a City Deal "win" with London – so cancelling it would have given the SSLEP a positioning headache with its relationship with London in regard to its ability to deliver on its commitments. After the change in administration within Stoke Council it took a further 6 months, from May 2015 to October 2016, for the DHN project to be essential re-reviewed and "re-signed off". Within this timescale work within the Stoke Authority on the City Deal proposal did not stop, this was related to the delivery timeline set by London; as well as this, if on the project had of ceased funding from London would have also stopped, delaying the process further.

The delay and reassessment process meant that Stoke-on-Trent City Council had a reluctance to "promote" the upcoming project, the earlier administration had undertaken an initial level of promotion even undertaking a televised item on BBC Midlands News in 2013 where they outlined that early studies for a DHN powered by geothermal power from deep under the City Centre look feasible. This was taken as the indicator that there was potential for local commercial engagement – the regional Business Chamber, the Staffordshire Chamber of Commerce, lobbied the Council for it to be allowed to start an information campaign with the business community. Stoke-on-Trent City Council were very reserved and would not allow this to happen until they were further down the project delivery path with no date given – no clear explanation was given and so consequently there was little progress of developing local public DHN/DE supply chain support mechanism. The officers who were developing the team were keen to get the local supply chain up to speed but they were as a priority charged with “delivering” the DHN project and could not spend time on economic regeneration activity with supply chain development.

Within the Authority the group who likely could have driven this supply chain engagement the Inward Investment / Make it in Staffordshire teams were in late 2015 and throughout 2016 given the priority of promoting the Ceramic Valley Enterprise zone. Combined with this the Stoke authority was undergoing a further staffing reduction cycle in line with the austerity cuts in which resource to drive and support supply chain diversification was cut.

The aligned SEND project at Keele University which is running to a differing timeline in part due to its aims and in part due to delays in its funding sign-off following the EU referendum vote, when all EU related funded projects utilising ERDF or ESIF funding, were put on hold for three to six months (noting the Stoke DHN was not affected by this as its funding comes directly from Central UK Government). But there is a fundamental difference with the Keele project and that of Stoke – whilst they both have a high “hardware” content with the physical aspects of the projects, the Keele project profile has an equal dimension of promoting supply chain engagement in smart energy technology innovation, therefore when the Keele projects starts it will focus outwardly for promotion and engagement into the local (and UK) supply chain base.

This seems to be a far better approach and it would have been far better for the Stoke DHN project to have had within its target deliverables a specific supply chain engagement element. At this stage in the DHN project cycle with procurement about to start any focus on supply chain will likely result in the bizarre situation that local and regional companies will see the opportunity with Stoke as too late for them to develop and diversify for; but will have the non-local Decentralised Energy DHN projects in other parts of the UK, for example in Bristol, Tottenham, Deeside and elsewhere, as targets for them to prepare and bid for.

Therefore, it can be viewed that due to a lack of supply chain promotion the local business sector in Stoke-on-Trent will see a high non-local activity with a probability that it will come from outside the UK. This will be very bad and could be bad for the SSLEP that it gets the DHN project built but has largely missed the opportunity for winning the placement for the Decentralised Energy DHN supply chain home in its area after promoting as such in its original Powerhouse proposals.

4.4 - Aims and policies of regional economic regeneration strategies

To compare the potential for regeneration strategies firstly we can consider experiences of market transitions in energy generation and supply and how it has affected market dynamics including hardware and service supply diversification, energy pricing, security and supply and effects on Greenhouse Gas emissions. As a prime example of this we can consider two case studies:

1. Sweden transiting from fossil fuelled energy supply to a district energy (principally district heat) market.
2. Munich moving to self- sufficiency in energy generation and supply

These case studies are being presented as they each have comparable drivers and deployment situations as for the United Kingdom district heat network and decentralised energy projects now in varying stages of feasibility study, design or deployment. The Swedish case study shows how varied national drivers over a long period have resulted in a situation that has given a high level of national energy security combined with extremely low CO_2 emissions from heat production – which is something the United Kingdom is aspiring do achieve as in its 2012 Heat Strategy paper by DECC.

The Munich case study explores how an individual city is building the key foundation steps to move to toward an energy security situation to be self-sufficient and off a national grid system by deploying high levels of district heat provision and also to utilise a deep geothermal power source. This deployment model of need and resource is comparable to the Stoke-on-Trent situation with its district heat and deep geothermal heat sourced project.

These case studies represent a comparable analogy to the national and local policy and drivers present in the United Kingdom to move to higher levels of distributed network heat.

4.4.1 - Case Study 1: Sweden – A move to District Heat

Sweden in the early 1960s driven by a policy of its central government set out to build one million new apartments by the mid-1970s. As part of this national development the new builds had to be integrated into new or existing District Heat Networks.

In the mid-1960s Sweden’s population was c5 million and there was under a general socialist central government approach a need to gain strategic independence from imported fuels and the dangers that would bring with price and supply security. In this respect, Sweden is fortunate that it has a large biomass fuel stock from its indigenous forest estate and it also has already undertaking a move away from landfilling residential and commercial wastes and implementing a country wide policy of recycling, reuse and utilising the remainder as a fuel stock in energy from waste plants.

Therefore, as shown in Figure 27 from the mid-1960s forward Sweden has now moved into a situation where it is fuel self-sufficient for electrical generation and meeting space heating needs, the population is now circa 9million and the level of space heating in integrated heat networks is at around 55% - which is viewed as nearing the limit of practicality.

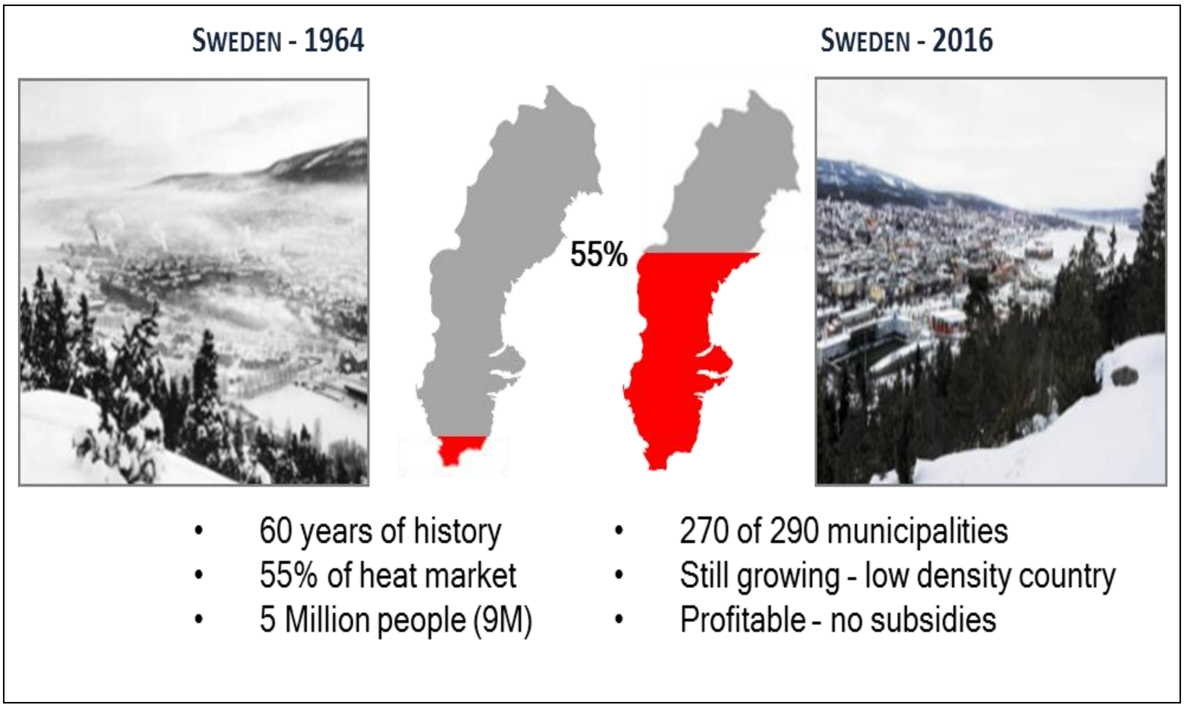


Figure 27: Infographic Transition in Sweden to District Heat Networks (Swedish Energy Agency, 2016)

The percentage of heat network supply has grown to this high level and been driven by situations that have arisen periodically:

- 1960s - Need for major growth in housing – 1,000,000 new homes
- 1970s - Oil crisis
- 1980s – 1990's - Environmental – fossil fuel related GHG emissions
- Market saturation from the late 1990s has led to competition and new service offers
- Sweden's network take-up has been followed by Denmark and Finland who have similar underlying inherent fuel security issues – with no to little fossil fuel resource.

As can be seen from Figure 28 as well as the growth of DHN in the overall Swedish Heat supply market there has been a major corresponding reduction in Fossil Fuel usage in heat delivery.

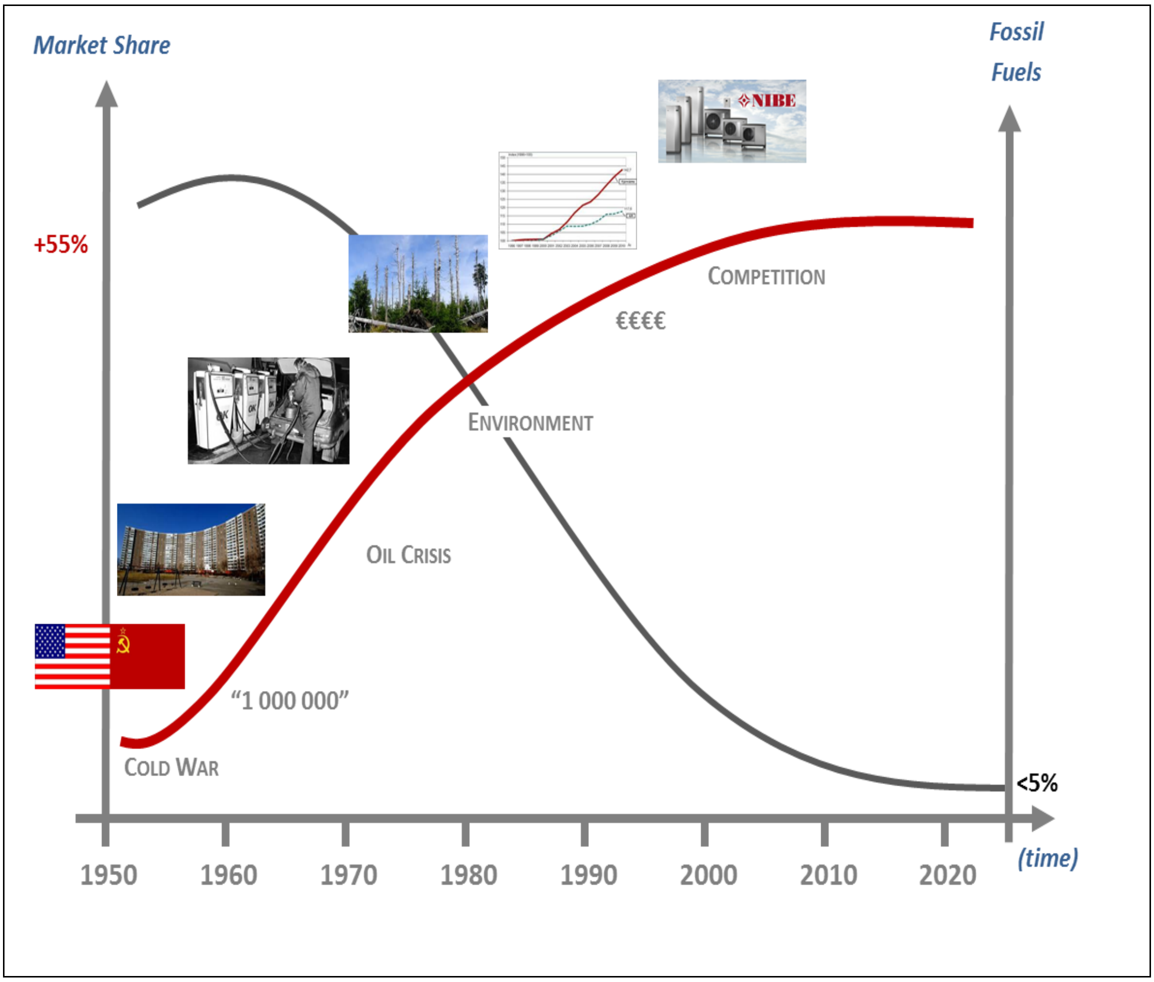


Figure 28: Swedish Growth in DHN in Heat Supply and the Decline of Fossil Fuel usage (Swedish Energy Agency, 2015)

This has had consequential effect in Sweden seeing a major reduction in CO_2 emissions – this markedly started to occur exactly at the same time as Sweden moved into DHN provision from the mid-1960s. This divergence is clearly demonstrated in Figure 29 where Sweden's CO_2 emissions show a reversing trend from around 1970 as compared against the Global increase.

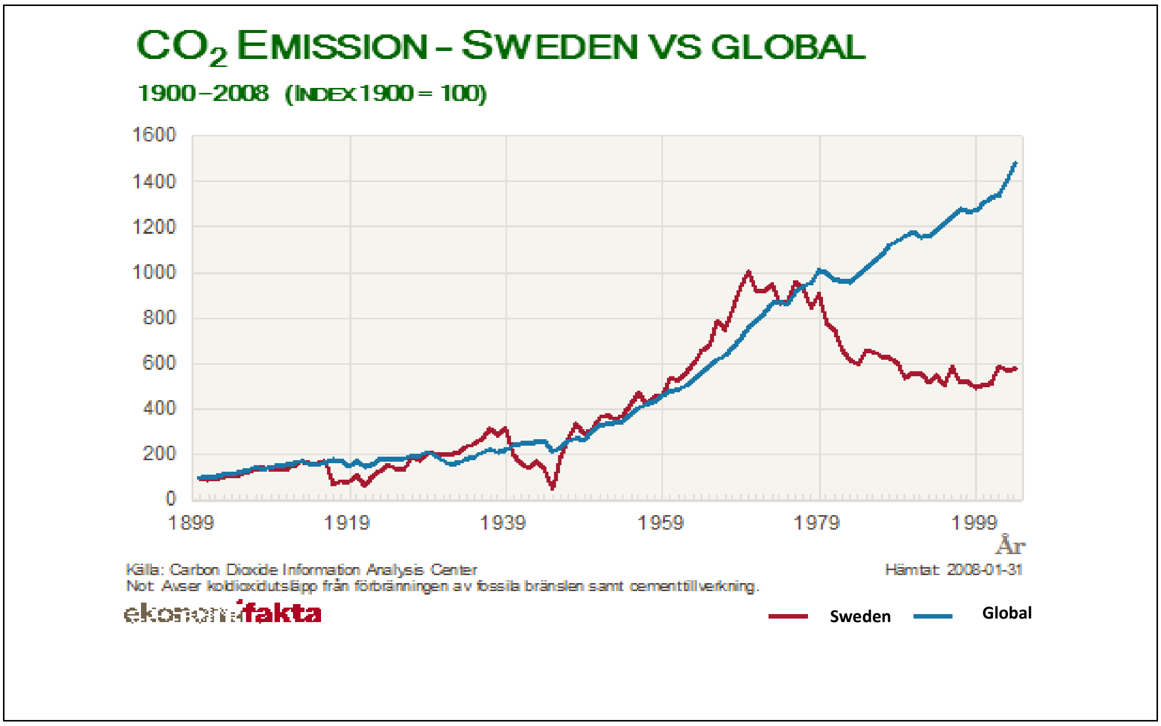


Figure 29: CO2 Emissions – Sweden vs Global (based on 1900 Index 100 point) (Swedish Carbon Dioxide Information Analysis Centre: Kalla)

With 55% of all of Sweden's heat needs being delivered in networks and in city and urban areas such as Stockholm, Malmo, Helsingborg rates are at over 90% heat delivery through networks. The balance of heat usage is now in isolated individual properties which are viewed as being added incrementally at later stage or viewed as being too expensive to add to a network.

The effect of this has seen Sweden over the last 50 years emerge with a wealth of operational experience with an established supply chain ranging from professional services for system design, legal, financial to piping manufacturers, to biomass boilers systems engineered for heat networks thus creating an economic dynamic resulting in inward investment and spend within Sweden moving virtually completely away from spend out of country to support imported fuel stocks (other than related to transport fuel use).

This slow progressive 50 years move into a country wide and now nearly saturated DHN situation at 55% of heat delivery means Sweden saves around 3 Billion Euros a year in foreign exchange payments it would have made for natural gas and heating oil supply (Swedish Energy Agency: Energy in Sweden: Facts and Figures 2015). This has been continually re-invested into ongoing DHN infrastructure. This has allowed a strategic and well-structured supply chain to become established across the country.

This Swedish DHN supply chain is now becoming export orientated with the Swedish DHN market now only growing slowly. Backed by the Swedish Government and the Swedish Energy Agency under the fronting up name of the “Heat Networks”, where Heat Networks is a joint network of leading suppliers of technology and services and industry associations. Their aim is to promote collaboration and facilitate knowledge sharing between Sweden and the UK to accelerate the development of heat networks. Therefore, a range of Swedish and other Scandinavian DHN companies – from pipes, valves, boiler systems, operators to engineering design consultants are establishing the Hotspot concept around the UK and Europe to allow them to identify projects and partners to bring their skill and knowledge base into the market place. They have identified eastern Europe as having a Soviet legacy of aging DHN systems which will need replacing or modernising. The UK with the DECC 2012 Heat Strategy is identified as a large market moving into DHN technology with its HNDU funded local authority projects in differing development stages.

The Swedish/Scandinavian supply chain whilst pursuing the UK projects is looking to tender for the projects in partnerships with UK companies – due mainly by the fact that the UK market prospect is viewed as so large it would be difficult to approach it without working in collaboration.

For the SSLEP, with the SEND and Stoke-on-Trent DHN, there is the prospect of a “Hotspot” being based in the SSLEP area. This gives the local business community an opportunity to work with knowledge and skill sets rather than a sole diversification approach. There is potential for low carbon business growth- small / medium / large market opportunities working in partnership. The Swedes have successfully developed their DHN opportunity and now they are planning an export drive with the UK as a principal target as per the “Nordic Heat” Masterclass sessions held in the UK in 2015 and 2016.

These Nordic Heat Masterclass sessions have been planned to cover DHN project development and deployment aspects such as: Finance, Technical, Communication, Supply Chain needs and opportunities. There has also been Masterclass sessions allowing local authorities to present their own project profiles and for companies to present their services – this in the main has seen Scandinavian companies being able to present their "wares" in a dedicated fashion parade. There also has been business partnership brokering between Scandinavian companies with deep technical experience and UK companies who are knowledgeable with UK regulations and needs, who wish to utilise their skill sets in a combined manner to gain a presence in the new DHN/DE marketplace

What is needed is a complementary support activity by the public sector such as from SOTCC, SSLEP and BEIS. It is worth noting that BEIS originally orientated the Swedish Heat Networks grouping towards forming a presence in Stoke-on-Trent, due to the flagship DHN project it was supporting. There is now a need for a targeted support programme to tie in the Heat Networks into the area and to match make partnerships between companies as part of building a home based, SSLEP supply chain which can gain a part of the national DHN/DE opportunity and gain GVA growth

4.4.2 - Case Study 2: Munich – a city wide power & network vision

In the state of Bavaria in Southern Germany the geotechnics are ideal conditions for hot water at the relevant depths. Much of southern Bavaria is located on the layers of Late Jurassic rock formations called "Malm", where there are porous, karst highly permeable rock layers.

Over the last twenty years, towns in Bavaria have developed geothermal projects. Located to the south of Munich in southern Germany the community of Pullach im Isartal has been operating a deep geothermal CHP plant operated by Innovative Energie fur Pullach GmbH (IEP GmbH) since 2005. This is a double borehole system, with one acting as the extraction borehole through which hot water at 102oC to 107oC is pumped to the surface from a depth of 3,500m and fed into a heat exchanger system. In the heat exchanger, heat energy is transferred into a separate water circuit and heated water is supplied directly to consumers. In Pullach, consumers are both private residential and public consumers – the Pullach town hall, public swimming pool, schools and medical institutions. The

Pullach district heating network extends to 25km.

Building on this operational experience in Bavaria, the city of Munich is aiming to be heated 100 per cent by renewable district heating by 2040, with geothermal energy set to play a major part with a plan for some 50% of the heat load to be from this source (Project GRAME. 2015). To better understand the geothermal resource and how best to access it and develop it in large DHN scheme a research project was setup in 2015 (Project GRAME – One Step towards our 2040 vision of 100% Renewable District Heating in Munich, Hecht, Frank, Petl, 2015) GRAME is funded by the Federal Department of Energy of Germany and managed by Stadewerk SWM Munich. The GRAME project timetable as shown in Figure 30 developing the model for an:

1. optimized and sustainable thermal reservoir development for deep geothermal thermally powered plants in the Bavarian Molasse basin
2. and design for a 50MWe (electric) power plant and development of a 400MWth (thermal) District Heat system for Munich.

Figure 30: Project GRAME Timetable (SWM, 2015)

The GRAME project is considering a range of topics that would support the deployment of points 1 and 2 above covering:

- 3D Seismic survey
- Reservoir drilling and engineering
- Standardising well design

- Development concept for 400MWth DHN system
- Financial modelling of Geothermal DHN for Munich based on 400MWth system load

Figure 31 shows the GRAME seismic survey heat contour map of the Munich city area with surrounding environs, with Pullach and the city centre area identified.

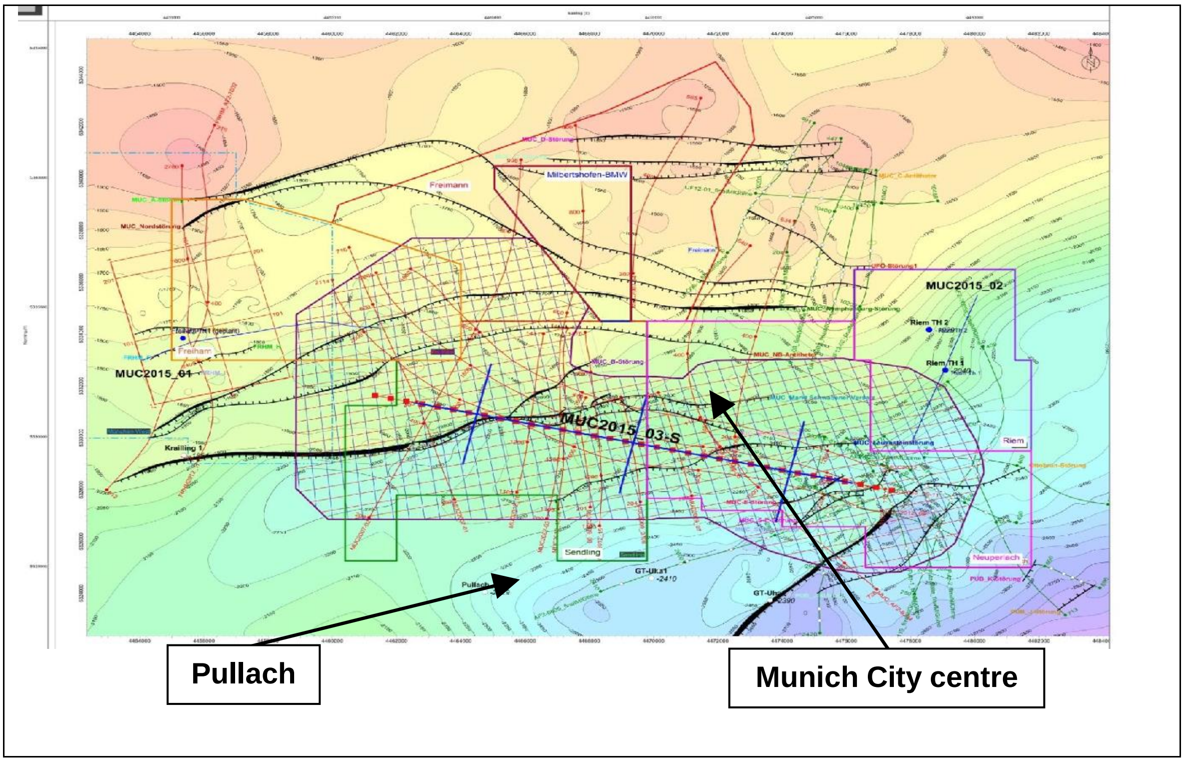


Figure 31: GRAME Project Seismic surveys Bavarian Molasse Basin (Project GRAME, 2015)

These Geotechnical seismic surveys of the city’s and surrounding subsurface have been undertaken including the use of “vibro” trucks as shown in Figure 32 to perform 3D seismic tests to fully appreciate Munich’s geothermal potential.

These seismic vibrator trucks have a system that inject low-frequency vibrations into the ground, by transferring power from a mounted diesel engine to a piston-reaction mass drive via an electrohydraulic servo valve. This form’s the hardware of the ‘Vibroseis’ exploration technique which was developed by the Continental Oil Company (Conoco) during the 1950s. The technology mounted on vehicles can induce low-frequency vibrations with a force up to 90,000lbf / 4 MN, it is viewed that by 2016 seismic vibrators can be used in around 50% of all land based seismic survey (Vibroseis, NA Ansley, Prentice Hall, 1991).

Figure 32: Truck train with mounted seismic survey 'Vibroseis' technology (SWM, 2015)

The city is planning to start drilling in 2018 to depths of 4,000 meters, with preparations to start in the autumn of 2017 the depth related temperatures are shown in Figure 33 which gives a cross section north to south through Munich with a geothermal drill site at Sauerlach which is targeting the subsurface aquifer with a predicted temperature of 140°C.

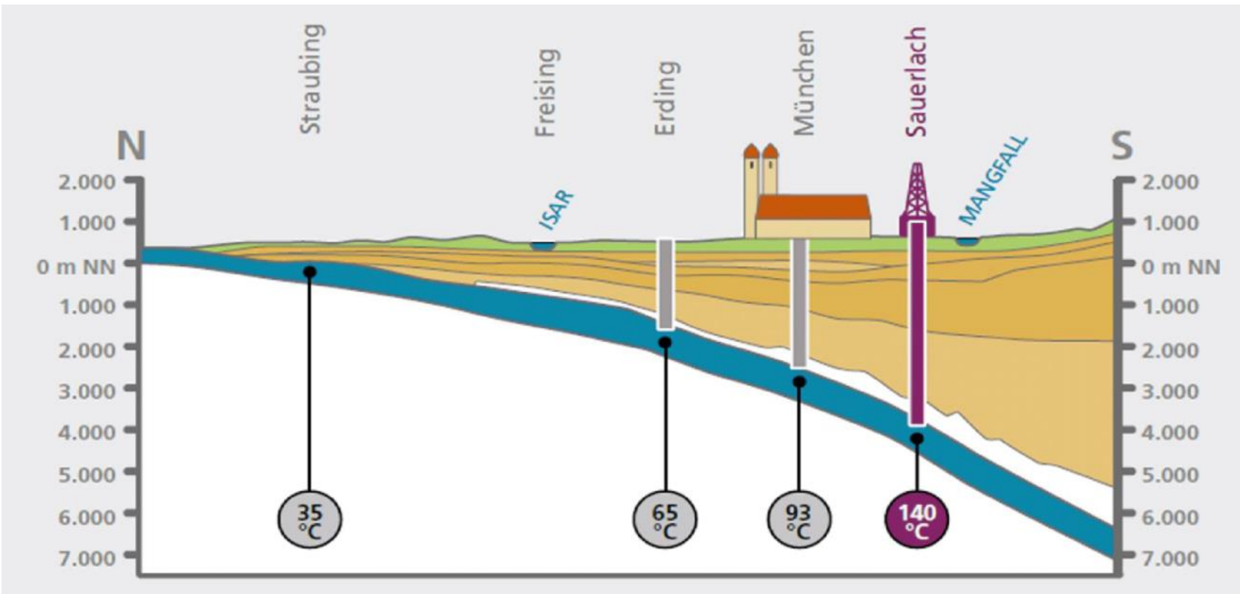


Figure 33: North – South section Bavarian Molasse Basin: Project GRAME (SWM, 2015)

Figure 34 shows the level of aspiration for the long term SWM plan for Munich – for the 50MWe electrical generation and 400MWth DHN system – powered by deep geothermal stations interlinked with other power generation systems to give an integrated solution for Munich.

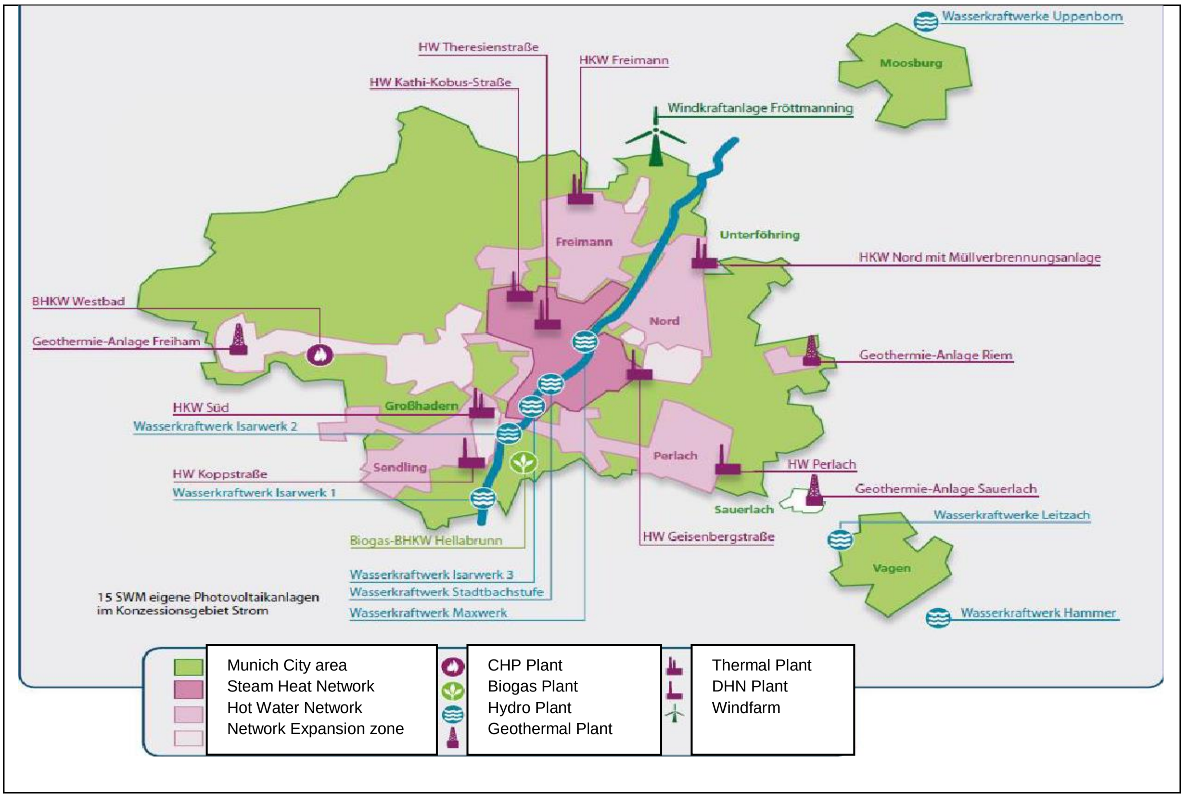


Figure 34: Schematic map of the Munich area with plant, networks and sector zoning (SWM, 2015)

These two case studies covering Sweden and its history of DHN deployment and growth to be giving 55% of the national heat delivery and the major Decentralised Energy infrastructure project in Munich are excellent examples of what can be done with the right national and regional policy drivers in place.

The principal driver is to gain a significant reduction in CO_2 emissions and to gain energy security of supply. Relating to energy, there is a direct legal obligation to meet GHG reductions; whereby fines for non-compliance can be issued. Coupled with this is the need to give industry and commerce, as well as the residential populace, a clear security of supply as this ensures economic certainty for businesses; something which the UK does not have at this time. This was experienced in the Stoke-on-Trent and Staffordshire region in 2010 relating to the national cold weather situation at the time.

The Munich GRAME project and the Stoke-on-Trent decentralised energy DHN are relatable, as they both experience commonalities in synergy; this is not just related to them having an aspect of being powered by deep geothermal heat – it is in the fact that both cities have an aspiration to be self-sufficient in terms of energy supply – being able to give operational security of supply to its businesses and residents.

This is a high aspiration, and it is the ultimate expression of pursing the application of decentralised energy. It means the two cities will be able to optimise the generation versus load and even operate their systems to export to the grid at high external demand peaks potentially generating revenue streams for the governing authority. The opportunity of a revenue stream for the sale of excess generated power, which would be exported into the national grid as and when the smart grid requires, it would be a useful input to support an authority's services provision.

It would be a useful consideration if the two cities had a partnership protocol for the exchange of information to assist each other. It is likely considering the scale and advancement of the Munich development that Stoke-on-Trent would learn most, this then would disseminate out into the wider UK decentralised energy DHN deployment as being driven by HNDU in BEIS. Areas of synergy that could be shared:

- Geotechnical survey comparisons – heat aquifer volume details, borehole data,
- Geothermal system design,
- Heat network design,
- Non-geothermal heat generation systems – model approach to finance / technology / adaptability,
- Load analysis and balancing models for business / industry / public sector / residential
- Communication models into business and residential.

4.5 - Economic and regulatory frameworks driving "Decentralised Energy"

Under the Labour Government of 1997 to 2010 there was a regulatory need for local authorities to gain an understanding of the opportunities for decentralised low carbon renewable energy generation within their area of responsibility. To this end, local authorities commissioned renewable energy studies to understand the range, number, type, generation level of renewable technologies that could be deployed within their regulatory boundary. This then allowed the Authorities to both be prepared for planning applications, and to also consider carbon emission reduction potential in regard to their KPI measures known as National Indicator, NI 186. This NI 186 was part of the regulatory framework that the European Union, and thus the UK, have put into place due to their obligations under the Kyoto Protocol and the UNFCCC (United Nations Framework Convention on Climate Change).

In the UK, the Climate Change Act 2008 establishes a long-term framework to tackle climate change. The act aims to encourage the transition to a low-carbon economy in the UK through unilateral legally binding emissions reduction targets. This means a reduction of at least 34% in greenhouse gas emissions by 2020 and at least 80 percent by 2050. A fourth budget period has recently been proposed which would see reductions of 60% by 2030. Within the Act the NI186 sat as the measure for local authorities within the structure; this structure is shown at a high level in Figure 35 covering the GHG emissions by Local Authority covering Domestic, Commerce and Transport:

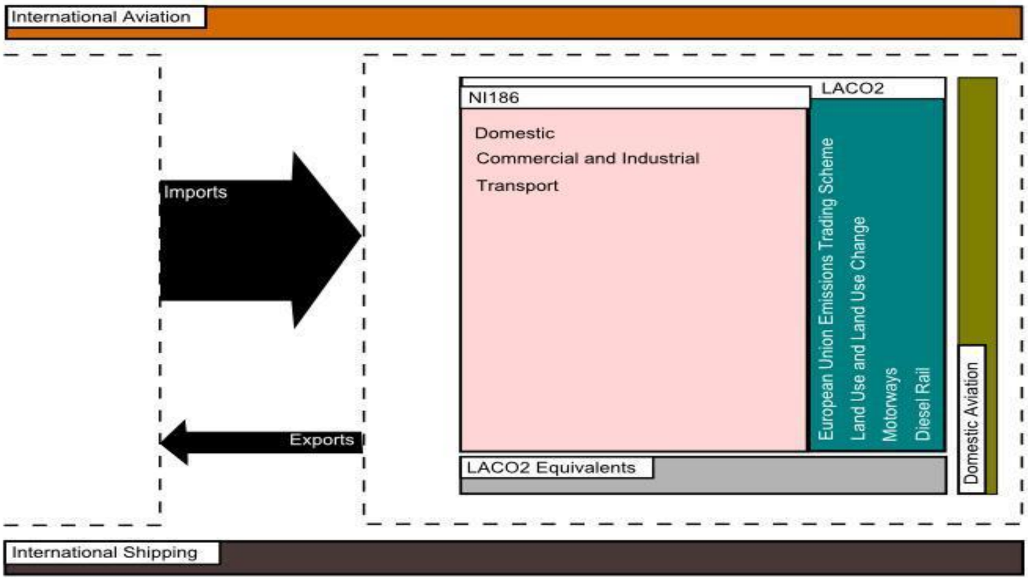


Figure 35: N186 GHG Emissions Top Level Sectors (Linton Hartfield, 2011)

To obtain this understanding of "their local" Renewable Energy Potential it was normal for local authorities planning departments to commission the studies to assist with policy development and preparedness for possible planning submissions.

The Unitary Authority of Stoke-on-Trent in 2008 the Housing Department commissioned Wardell Armstrong LLP to undertake a 'Renewable Energy Scoping and Feasibility' study. The resulting study, which is in the public domain, informed the City Council of the potential for renewable energy generation and guidance on how the City Council can install renewable energy generation capacity in order to firstly meet and exceed its share of the regional renewable energy targets and secondly reduce the number of households that are experiencing fuel poverty due to rising fossil fuel prices.

The 2008 commissioned study comprised an assessment of large scale generation and micro-generation for integration into the existing housing stock, examining a variety of technologies in turn.

These renewable opportunities studies for Stoke-on-Trent City Council had twelve key objectives to be achieved were:

1. *An assessment of existing and future energy demand.*
2. *To consider the local Development Framework and Core Spatial Strategy when anticipating how many new build units will have their domestic energy requirements provided by renewable energy sources.*
3. *An assessment and review of large scale renewable generation.*
4. *An assessment and review of micro-generation technologies.*
5. *The assessments will have to consider the technological, environmental, legal and planning issues or constraints for each form of renewable energy technology.*
6. *To carry out a financial appraisal that will include a cost-benefit and payback analysis for each form of renewable energy technology.*
7. *Produce recommendations on what is the most viable and effective form of renewable energy technology to integrate into the existing housing stock in order to achieve the regional energy targets.*
8. *To identify and map potential locations that will maximise the financial, environmental and energy saving benefits.*
9. *Explore and identify potential funding opportunities.*
10. *Consider resident consultation and make recommendations to maximise community involvement.*
11. *The study will produce key milestones and targets that the Council will need to achieve in order to fulfil the climate change and fuel poverty targets.*
12. *To identify best practices and relevant examples for renewable energy technology used in similar types of housing stock within social housing elsewhere in the UK.*

The renewable options study identified that the overall objective of the study was:

> *"to ensure that the city has a robust evidence base in helping determine the most effective form of renewable energy technology to integrate into the existing housing stock in order to meet their share of regional and national climate change and fuel poverty targets."*

This study used a robust evidence base to determine the scope, range and form of possible renewable energy technology take-up in the council. Its emphasis was based around the demands placed by the social housing stock.

Over the course of further studies Stoke-on-Trent City Council developed an approach to delivering Warm Zone, and then ECO (Energy Company Obligation) finance packages to equip social housing stock with a range of efficiency measures such as improved insulation and solar PV. In addition to this, the council also developed a longer-term view for the city that was making the first steps to become self-sufficient in heat and electrical generation. This entails strategic developments to enable a move away from nationally based supply to indigenous supply; which then gives security of supply to commerce and business and the security on price for the fuel poverty agenda.

Stoke-on Trent City Council subsequently built this into the foundation for the Powerhouse Central concept that then developed in the Energy element of the SSLEP City Deal funding programme with central government, which is underway now moving into procurement for the Smart DHN system in late 2017.

The City Deal energy programmes are a two-way vehicle in that the SSLEP receives the funding packages to deliver the systems, and then associated businesses assist programmes to encourage and drive supply chain diversification into the decentralised energy sector. Central government needs to be able to de-risk decentralised energy heat network systems, to allow for wider take-up across the UK. This can be done though encouraging private sector investment models, and also delivering policy support programmes to help drive a national decentralised programme. This then supports the widening of the HNDU in BEIS (was in DECC) in terms of its remit and funding package options to local authorities which has been scoped in the UK Energy Investment plan 2014 (DECC Delivering UK Energy Investment, 2014).

4.6 - Decentralised Energy – Barriers, Drivers and deployment

While each decentralised energy and heat network is a unique place-based project with a specific set of challenges and requirements, there are a number of barriers and drivers that are common to every project. Research has been carried out by Frontier Economics who looked in detail at these and identified a set of issues acting as barriers, drivers, restrictors (Frontier Economics 2015) these can be characterised as:

- **Monopoly:** Heat networks are natural monopolies resulting in very limited competition. This contrasts with the current situation for most consumers who can choose their gas supplier and may be unwilling to lose that flexibility. There is a danger that a monopoly can create poor outcomes for consumers which can in turn cause wider reputational damage to the sector and become an additional barrier. The type of ownership model is key here as a monopoly based on a community owned approach may bring acceptable rewards outcomes for the stakeholder base, differing monopoly systems are an opportunity for further empirical modelling

- **Demand uncertainty:** Heat networks are presently capitally intensive with a long service lives of from 25 to 50 years and so investors are very sensitive to the level of demand, and therefore revenues, that can be secured over the life of the project. However, there can be uncertainty around the level of demand as consumers are often wary of signing into long-term contracts for supply, or the future number and operational characteristics of the buildings on the network may not be known in advance. More broadly this then creates friction with energy efficiency policy as, once networks are installed owners are likely to look unfavourably on any reduction in revenue from servicing heat demand that is brought about by introducing energy efficient technologies leading to unknown additionality effects.

- **Long-term commitment:** Heat networks have long asset lives and investments are made based on long-term revenues. Any shift in government policy during the life of a scheme can impact the business model, which increases the risks for investors. Heat policy can also disincentives investment in heat networks, either through incentivising competing technologies or by creating regulatory barriers such as planning restrictions.

- **Non-financial barriers for consumers:** The public awareness of heat networks is low and there is a widespread lack of trust in the energy industry overall. Where there is awareness of heat networks, there is sometimes the negative perception that they can lead to temperature variations over which homeowners have little control. In addition, as with other utility-based infrastructure projects, heat networks are inherently disruptive at street-level meaning very dense urban areas may be difficult to access despite their high heat demand.

- **Institutional barriers:** Local authorities are key actors in many heat network schemes, but they are often poorly resourced due to a limited skill base in the UK. Due to the limited number of existing schemes there is also a more general skills and knowledge gap within the sector.

- **Waste heat barriers to supply:** It can be difficult for developers and investors to gain information on the availability of waste heat for example from power stations and Energy from waste plants who act as conventional power generators. The use of waste heat from industry which could be of great interest can also involve complex negotiations and contracting between public and private actors and is often not a priority for industrial energy managers.

- **Lack of comparable projects:** Developing finance package for a heat network project is challenging because each project is unique and will have a different mix of customers, from large businesses, local authority buildings, social housing blocks or new developments. Therefore, it can be difficult to show investors an equivalent scheme in this country and thus compare the rate of return it provided. It is incumbent therefore on central government through policy and support programmes to lead the way and de-risk by exemplar projects

- **Attracting risk-capital:** There is a stage in such projects that is particularly risky and difficult to finance between the feasibility/design stage and the project being built. This includes legal work, seeking permissions, and consultation with stakeholders and affected parties. Projects can fail at this stage so the cost of capital for financing this work is very high. This has hampered the development of potential schemes.

- **Carbon price effect:** Heat networks reduce carbon emissions relative to most incumbent heating options, but the value of that carbon-saving is not reflected in the price of heating. Placing a sufficient price on carbon has proved to be very challenging both in the UK and internationally as shown by Garman, (2014) but until this is achieved the cost of heat networks relative to higher carbon options will remain a barrier.

4.7 - Decentralised Energy Technology – Stoke-on-Trent LEP Options

A range of unconventional energy sources are potentially available across the UK – a number relate to the geological situation, others relate to industrialisation and urbanisation, and then to organic material either from agricultural and industrial processes or from ground maintenance within the urban setting. These energy resources vary in their availability and practicality across the regions of the UK. When considering the energy potential in terms of being an economic regeneration driver for the Staffordshire area and within the city of Stoke-on-Trent there is a need to both identify the energy source, its potential, feasibility and its technical suitability for deployment.

Energy sources for consideration are:

- Unconventional Shale Gas, Coal Mine Methane and Coal Bed Methane
- Mine water Geothermal
- Deep Geothermal
- Industrial Waste Heat
- Biomass and Biogas
- Waste Materials
- District Heat Networks

These will now be discussed and reviewed individually – but it must be noted that they can be considered to offer the opportunity to be developed into an integrated energy offering. The energy sources also offer diversification opportunities for business as they are viewed to be "new" in the UK as the level of activity in terms of supply chain capacity and skill set resource pool is low due to only a few projects being developed in the UK. Business will only be able to take up the opportunity and diversify into the new emerging supply chains if they are made aware of the upcoming opportunity. This requires a concerted regional and national promotion and a marketing campaign by Government, Local Authorities, LEPs utilising business communication channels such as with the British Chambers of Commerce, University Business support programmes, ERDF (European Regional Development Fund) Business support programmes.

4.7.1 - Unconventional Gas – Shale Gas, Coal Mine Methane and Coal Bed Methane

Within the SSLEP area there are geological resources relating to carboniferous coal. This is well known and established as the Cannock and principally the North Staffordshire coalfield were key and influential to the Industrial history of the region, supporting both the ceramic and steel industries that existed from Victorian times through until today. The ceramic industry is still active and stable today, whilst the once large steel industry based in Etruria at Shelton Bar and also at Apedale Valley and the coal mining industry itself are now long gone.

The coal industry based around the North Staffordshire coalfield did not close due to the resource being worked out. In fact, the last NCB resource assessments made during the 1980s and 1990s on mine closures, and which were confirmed by Wardell Armstrong LLP (an international Engineering and Environmental consultancy who are a specialist in Coal reserve assessment) in a Stoke-on-Trent City Council study in 2010/11 viewed that there was still c1 billion tonnes of unworked coal reserves under the City area.

In 2010 Stoke-on-Trent established a Low Carbon Industrial Development Group – known as the LCIDG, membership was across the public and private sectors – with players who brought technical, policy, legal and financial knowledge being part of the group. The group was formed as part of the council’s response to the local industry calls for assistance following the fuel shortages experienced during the cold weather period in early 2010 when power brown outs were threatened by the energy suppliers to industry to keep public sector and residential suppliers running.

The LCIDG was tasked with developing decentralised energy sources and resources which could be developed to give a degree of localised energy security and, also the potential to allow off grid supply. A study was requested by the LCIDG, which as part of its remit was researching and identifying potential low carbon technologies specific to the Stoke-on-Trent area. The study was commissioned by the Regeneration Directorate of the Stoke-on-Trent City Council. This study had been specified to outline opportunities around exploiting what are termed onshore “unconventional gas” opportunities such as shale gas, coal mine methane (CMM) as from worked seams via methane drainage, coal bed methane (CBM) from unworked coal seams and geothermal energy as a localised energy source (geothermal prospects will be discussed separately in 4.7.3).

The potential for a shale gas option in the Stoke-on-Trent City Council Authority area was quickly put to one side in this study, as the local rock geology was not of a Shale Gas resource type – this is viewed as sitting to the West of Stoke under the Cheshire plain as this links into the shale gas field being developed with test drilling in Lancashire to the North. This is in line with the DECC/BGS Carboniferous Bowland Shale Gas Study – Geology and Resource estimation of 2013. Figure 36 shows the prospective Upper Bowland area and it can be seen the Stoke-on-Trent is just to the East of the Cheshire Basin area.

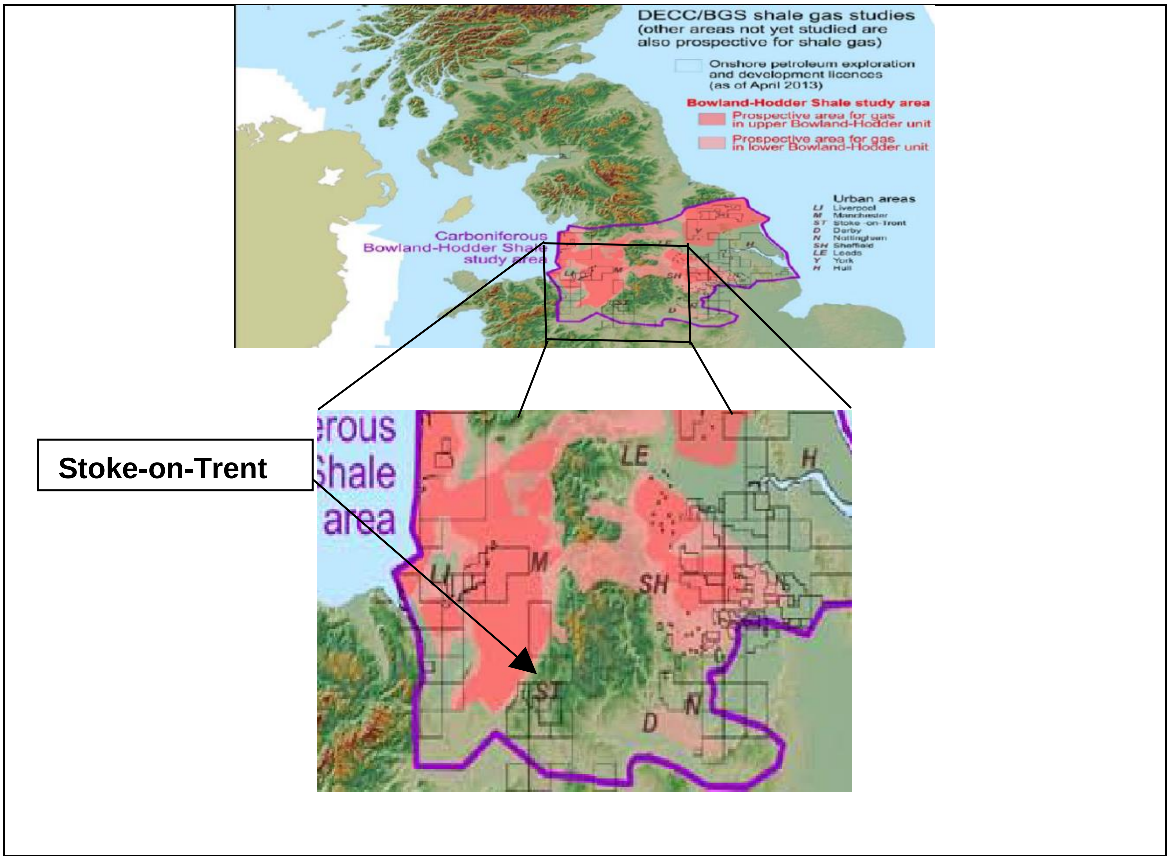


Figure 36: The Carboniferous Bowland Shale Gas Study (DECC / BGS 2013)

With shale gas viewed as not being a resource in the SS LEP remit – CMM and CBM were considered as resources for consideration supported by the excellent gas in seam records as kept by the National Coal Board (NCB) operational record keeping and now held by the Coal Authority.

Coal mine methane is being utilised in Stoke-on-Trent, the two principal sites being operated by Alkane and relate to taking the gas being evolved at the closed mine complexes of Hem Heath and Florence collieries. The gas is emerging from the old mine workings and is then pumped out of the unflooded upper workings or via the capped off shafts taken to on the surface gas engine units and generate electricity which is sent into the national grid. The operations are known as CCM Flexible Peak Generation sites as they can operate at peak pull demand times on the national grid running often in the mornings and then in the late afternoons into the evening grid demand profile. The generators are able to turn on and off the gas supply using the closed mine workings as a “giant” gas storage system.

In a CMM system as stated the gas evolves from the worked coal seam system, therefore as the gas is drained off to the surface, more gas is freed up from the coal surface due to localised partial pressure changes in the mined-out voids which have not flooded allow gas to become freed from the coal striation cleat rock microstructure. This is the same process that supports Coal Bed Methane (CBM), the difference being CMM is related to worked out seams, and CBM is related to unworked coal reserves. CBM and CMM extraction utilises “gassy” coal, these coalbed methane resources can be considered as dual porosity reservoirs in which the porosity relates to natural fractures within the coal which are known as cleats. The gas in unworked coal is then adsorbed and held in place by the present water volume – when the water is pumped out the hydrostatic pressure is reduced, and the gas is released, as is shown in Figure 37 of CBM Exploitation technology as from DECC (2011) in its paper Onshore oil and gas exploration in the UK: regulation and best practice.

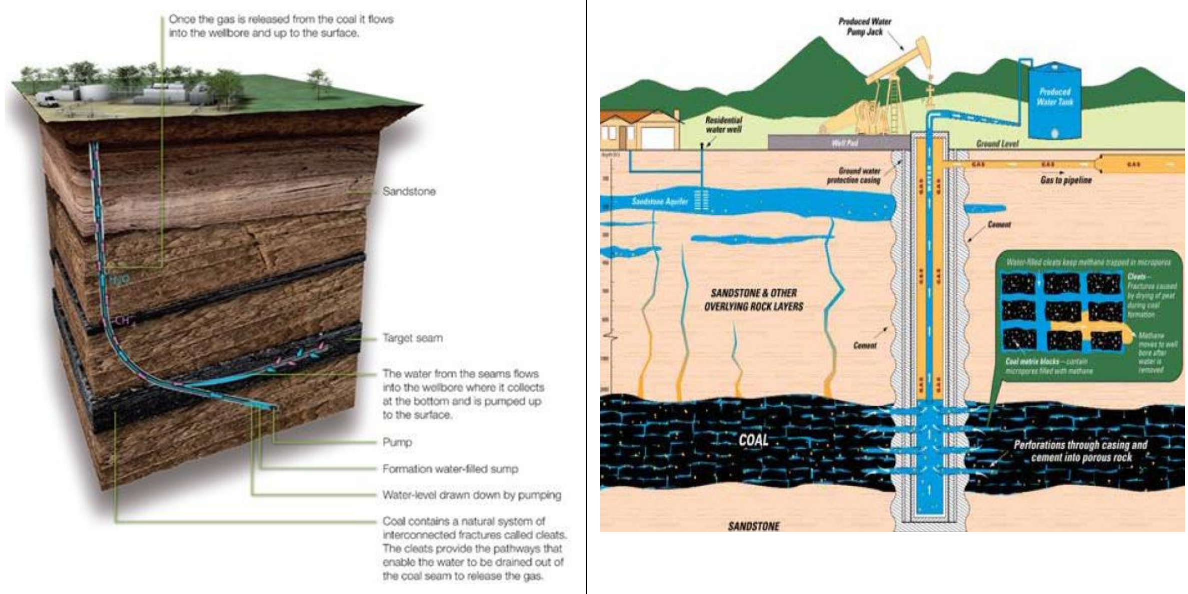


Figure 37: CBM Exploitation technology - DECC Onshore oil and gas exploration in the UK. (2011)

Analysis for Stoke-on-Trent City Council in its review of CBM and CMM resources was a study that formed part of the continuation work from the low carbon and renewable option studies concluded that National Coal Board (NCB) mine surveying records show that mine gas density as held within the coal striation rock structure increases with depth. This sees that gas in situ, within coal seams in the Stoke-on-Trent area, goes from c7.5m3/tonne at 600-700m depth to 10.5m3/tonne at 900-1000m depth. When this is applied to the unworked coal reserve in the North Staffordshire coalfield area, which is viewed at c1Billion tonnes, it can be evaluated that there is a potential in situ gas resource of c9 Billion m3 of gas potential with the majority in unworked areas so for consideration for CBM application. In the Wardell Armstrong study of the potential in situ CBM gas it is viewed that around 10% of this volume can be viewed as reserve worthy of consideration for exploitation with then a view that only 1% is economically viable as retrievable resource of 90,000,000m3 of CBM gas.

As this CBM gas is of a high methane content, and as such is viewed by the Digest of UK Energy Statistics (DUKES) to have a nett Calorific Value (CVn) of 36MJ/m3 this gives an energy value of some 900TWh of thermal input. This is of the value that would give 20 years of the heat requirement for the Stoke DHN project. During this study the potential CBM for use in the DHN was considered but for the present is viewed as “back on the shelf” due to political considerations for the local authorities to “be seen” as an exploiter.

Therefore, there is considerable unworked coal spread across 40 seams in the North Staffordshire coalfield that sits under Stoke-on-Trent and Newcastle-under-Lyme. This is viewed as a resource accessible by drilling into the selected coal seam and then pursing lateral directional drilling with de watering to lower the hydrostatic pressure to release the gas. Whilst the local authority in 2016 are not considering accessing the CBM gas, a commercial company called Norcross have won the PEDL rights from DECC in 2015 in the 14th PEDL round as per DECC PEDL Round submission report. The CBM potential considering seam and mining situations is further reviewed in Appendix II.

4.7.2 - Minewater Geothermal

Worked out mine areas in the UK are in most cases flooded after a predicted recovery time. This recovery to a flooded position is present within the North Staffordshire Coalfield, the worked-out coalfield on being closed down in the 1980s and early 1990s was placed into a position of three known flooded zones by the closing down mine engineers. These zones known as “ponds” which are physically isolated from each other by the closing of key cross-linking roadway doors at the time of the mine close down. The three ponds as shown in Figure 38 can be considered as:

1. The West Pond – west of the A500 spine running through the city –the key mines of Holditch and Wolstanton.

   On pumping being shut down at Holditch when this mine closed in 1989 this pond filled very rapidly being full within a few weeks of the closure.

   Evidence of this is that the Silverdale mine inclines in this pond are filled within 20m of the top of the inclines and are a Coal Authority monitoring point.

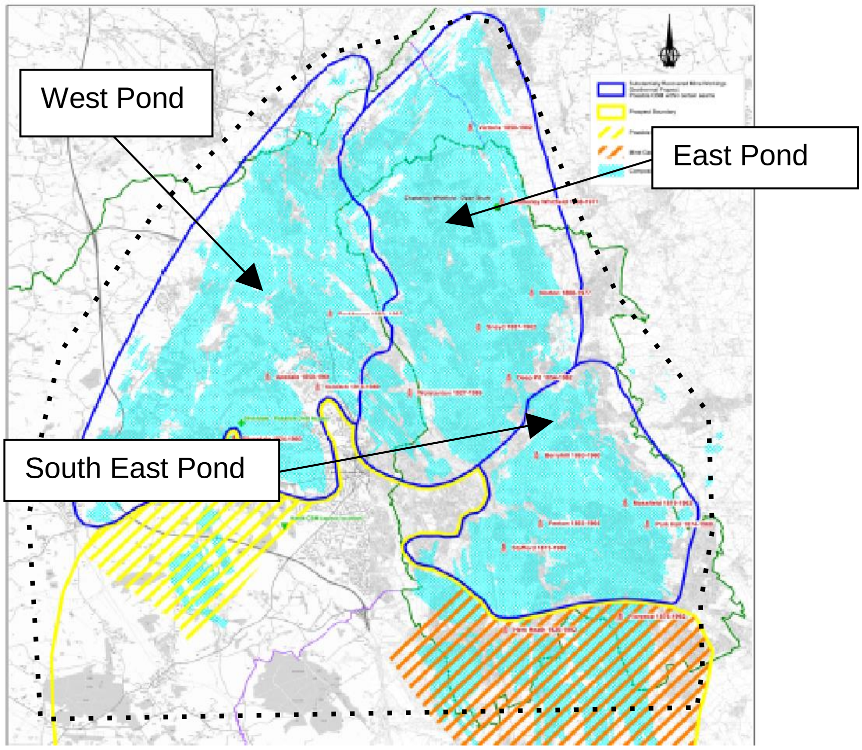
2. The North-East Pond – related to the Hanley Deep and Chaterley Whitfield mines.

This pond is now known to be filled – the main driveway under Etruria Valley was closed by Engineers cutting the link with Wolstanton pit. Also, the filled state is known due the outflowing of waters into the Harecastle Canal Tunnels at Kidsgrove and at the Ford Green brook – these are Coal Authority monitoring points.

3. The South-East Pond – related to the Hem Heath and Florence mine complexes.

This pond is still filling – this was predicted to take some 25 years from the closure of Hem Heath in 1993. The flooding is now believed to be at pit bottom of the main shafts and raising – the key measure is that the offtake pressure of Mines Drainage Gas, MDG, to the Alkane mine gas power generation centre on Trentham Lakes, is being seen to be falling away indicating the final stages of filling.

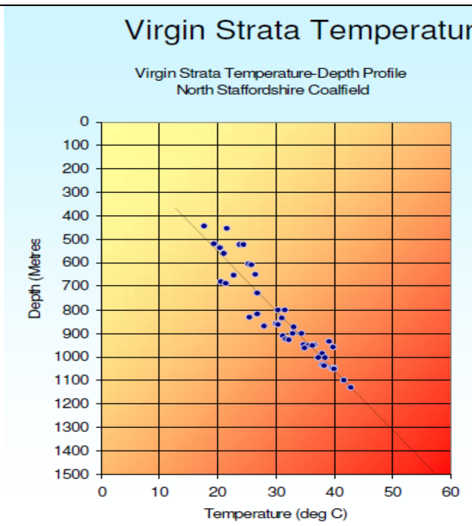
Therefore, in the urban setting of Stoke-on-Trent there is a need to understand how to pursue and utilise this as an energy resource and how it can be used for power generation from the natural heat that will be present in the flood water. It is well recorded and experienced that the mines in this area were hot at depth as a working environment at 30-40 degrees; there are many images of the miners working in a semi-naked state of dress due to the heat levels particularly at seam depths of 800m at deeper which are in the centre of Figure 38.



Boundary of North Staffordshire Coalfield shown by dotted line.

Figure 38: North Staffordshire Coalfield Flooded Areas (Wardell Armstrong, 2011)

The conditions of the three filled ponds, gives an energy opportunity in the form of minewater geothermal heat. Mining records taken consistently during the mines working operation show a clear linear relationship with depth – this is shown below in Figure 39.



Depth(m)	Virgin Strata Temperature deg C
1003	37.3
1006	38.6
1036	38.1
1038	38.3
1049	39.7
1051	40
1051	39.8
1051	40
1053	40.1
1100	41.8
1133	43

Figure 39: Depth Temperature Measurements – North Staffordshire Coalfield

These records indicate the possibility of a temperature of 60° C at 1500M depth, and potentially even greater temperature at deeper depths. The mine surveying temperature data as collected by the National Coal Board mining engineers allows seam related temperature contour maps to be produced. Two examples of heat seam contour maps are shown, as produced in a minewater geothermal study undertaken by Wardell Armstrong in 2011 for Stoke-on-Trent City Council. Figure 40 for the Great Row seam is considered as shallow at 283m below OD (Ordnance Datum), and Figure 41 for the Cockshead considered as deep at 1120m below OD based on Hem Heath pit in the south part of the city area marked as HH – Hem Heat pit head.

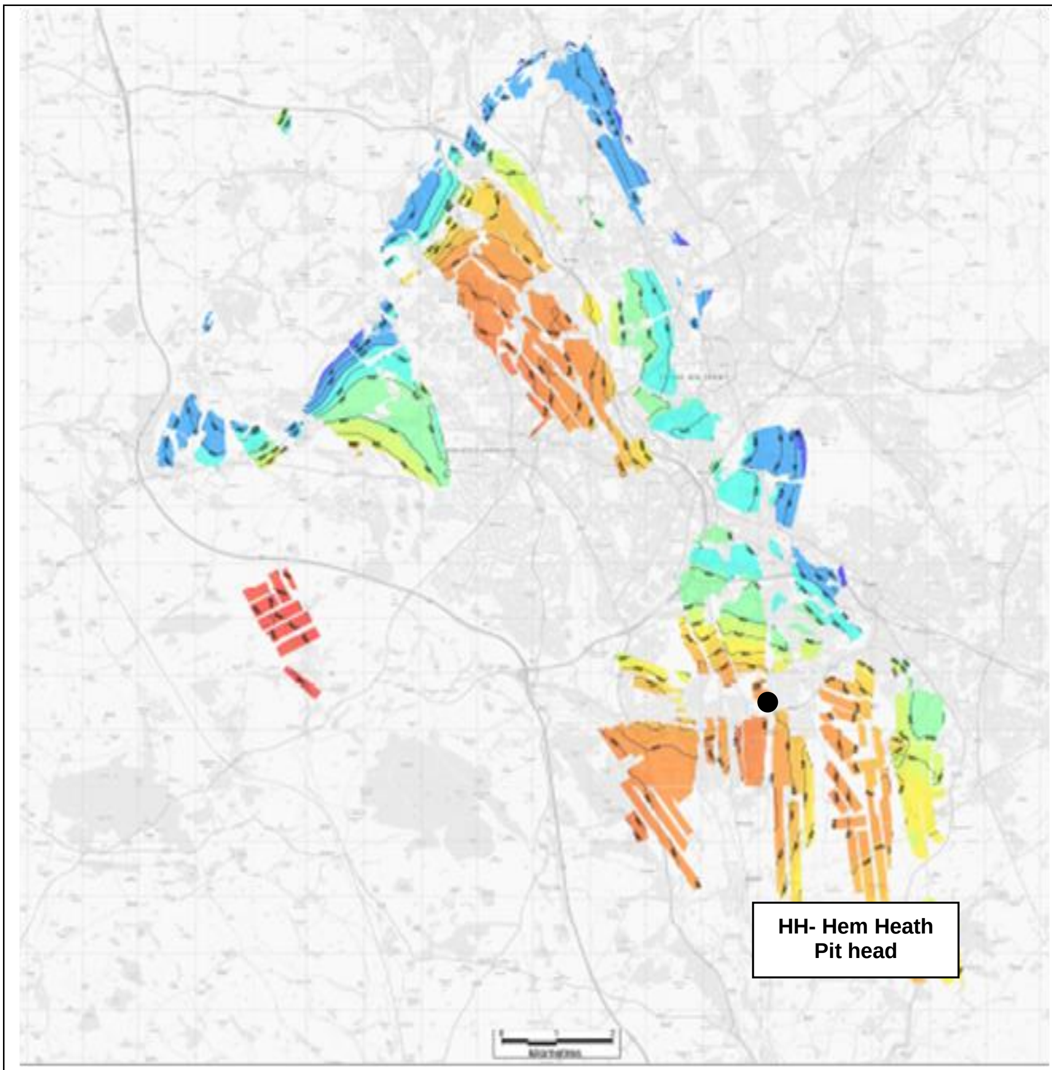


Figure 40: Heat contour map for the Great Row coal seam (Wardell Armstrong on the potential for Minewater Geothermal Heat, 2011)

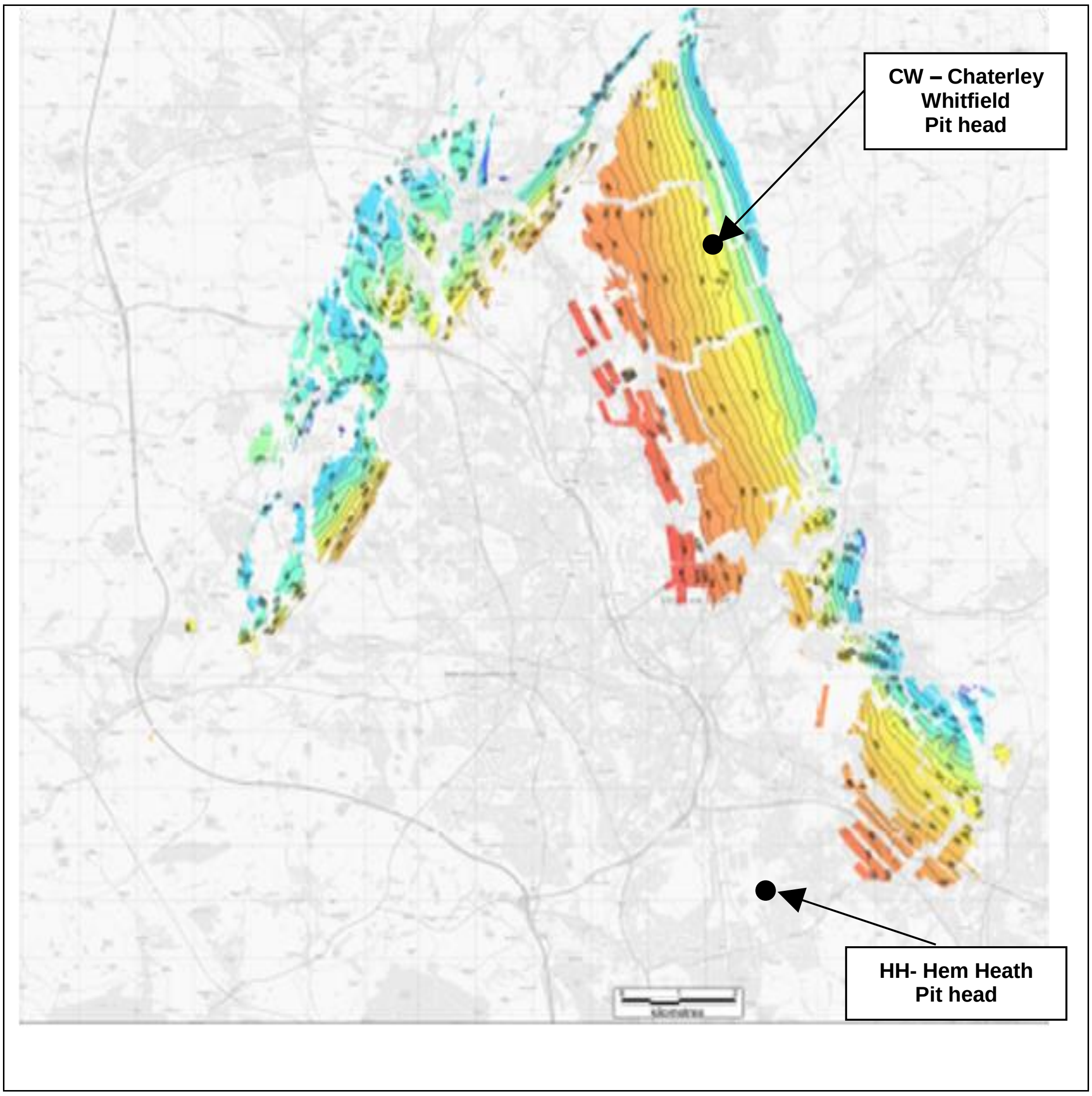


Figure 41: Heat contour map for the Cockshead coal seam (Wardell Armstrong study on the potential for Minewater Geothermal Heat, 2011)

These heat contour maps take other seams into consideration to give a complex underground heat map that can be used to see where hot spots lie in relation to heat demands on the surface. Aligning this with the Wardell Armstrong minewater geothermal heat mapping study, carried out in 2011, associated academic study work was undertaken at Keele University by Simon Hargreaves as his MSc dissertation. In this work, the methodology was researched and developed to create sub-surface 3D visualisations of the mining system and the associated heat in the flooded sections.

This approach to subsurface mapping enabled areas to be identified for potential access points to seam hotspot areas. Further to this Stoke-on-Trent city Council has under its ownership the Chaterley Whitfield business park, which is sited on the old Chaterley Whitfield mine complex.

The mine is sited on the edge of the North-East pond of the flooded-out areas as shown in Figure 41 with the mine noted as CW Chaterley Whitefield pit head. Chaterley Whitfield closed as a working mine in 1976, it was the first mine in the UK to draw 1,000,000 tonnes of coal in a year in 1937.

Whilst conventional mining finished in 1976 access to the workings was maintained as it operated as a mining museum. Visitors descended the Winstanley shaft a drop of 210 metres feet and explored a series of workings at this depth. These workings were only a fraction of the total extent of Chatterley Whitfield workings extended for miles and in the 1930s were in the region of 50 miles of roadway in operation. The mining complex when working had a number of coal winding shafts such as:

- Institute
- Middle
- Plat
- Winstanley
- Engine
- Hesketh

The Hesketh shaft was the deepest at Chaterley Whitfield at 2,000 feet – 610 metres so it was the deepest point for pumping water out of the mine complex. For example, in 1930 it had 16 underground pumps, and the average amount of water pumped out of the mine in a 24-hour period was 542,000 gallons (2.46 million litres). This water was pumped into a pond on the surface and was “lost” into the surface drainage system.

This local run-off still occurs even with no pumping activity as it is known locally that in the Autumn and Winter run-off from the now flooded system near to Chatterley Whitefield, at Ford Green Hall, appears in a local stream which can steam due to warm minewater outflow in cold weather.

Due to restructuring of the UK mines after their nationalisation in 1947, when the National Coal Board (NCB) was formed, in the 1950s mines were brought together to work together physically underground as part of a rationalisation plan. This resulted in Chaterley Whitefield being linked to surrounding pits such as Hanley Deep and Wolstanton.

Towards the end of Chatterley Whitfield's last operational days, it was connected to the nearby pit of Wolstanton via a 4-mile underground passageway. Wolstanton had shafts descending up to 3,000 feet (914 metres), and as it was the last working pit in the area, it was responsible for pumping. This had a direct effect on Chatterley Whitfield as it was high at 2,000 feet (610 metres) the pumping drained the 'Higher' workings – Wolstanton pit bottom acting as a sump for the whole interconnected underground roadway system.

In 1981 Wolstanton Colliery stopped coal production and after a period of salvage work, the pumps were turned off in May 1984. This meant that the water present would gradually rise to its natural level and slowly flood the abandoned workings at Wolstanton and then eventually Chatterley Whitfield – this flooding occurred resulting in the mining museum closing in 1986 when it lost access to the workings.

Whilst it is normal practice in the UK for closed mines to have their shafts filled and sealed in most cases, the Hesketh shaft was capped with a concrete lid with measuring points fitted. The means that the Hesketh shaft at Chatterley Whitfield offers the opportunity of access into the edge of the flooded area through this cap but still accessible Hesketh mine shaft.

Stoke-on-Trent City Council commissioned an assessment of the water column temperature in the Hesketh shaft in 2011. This proved inconclusive as it was expected to be able to reach a depth of c600m to pit bottom but on undertaking the test it was found there was a blockage in the shaft at between 200 to 300m. This blockage meant that the full water column could not be measured for a delta in temperature change. As of mid-2016 this has been unresolved, so further analysis is on hold using the Hesketh shaft as an access point until the blockage issue has been resolved.

Consideration is still being given to the potential of Minewater geothermal by the SSLEP and Stoke-on-Trent City Council even after the inconclusive Hesketh shaft step test study as it is known the mine system in North Staffordshire is hot from NCB daily record keeping.

Using this database, held today by the Coal Authority who act today as the official custodian of all UK mining records, as part of the Minewater Geothermal Study, Wardell Armstrong in 2011 suggested that Minewater as extracted from a flooded seam or targeted roadway at some 500m depth would give around a 25^{o}C Delta T in temperature change which extracted at 40ltrs/s could yield 3.3MW of thermal energy which would give around 28.9GWh over 8760 hrs or 1 year.

Taking into account losses from the heat exchanger systems at a potential 50% this still suggest a useable space heating resource of 14.5GWh pa, when compared to the Stoke-on-Trent DHN schemes heat demand of 48GWh pa. This represents a requirement of $1.3x10^6$ m3 of Natural Gas based on a CVn of 40MJ/m^3 for Natural Gas (TRANSCO Calorific Value Description http://www2.nationalgrid.com/UK/Industry-information/Gas-transmission-operational-data/calorific-value-description/ as of Summer 2016).

Beyond the North Staffordshire Coalfield there are other flooded hot water coalfields known in the Coal Authority database – these are of interest to central government as sources of energy for space heating. A hinder to this moving forward is a lack of a supply chain specific to the technology as required and, also a lack of governmental regulation on how minewater geothermal should be licensed.

The lack of methodology for licensing is being worked by on Whitehall as it is viewed to require an aligned approach also to deep (non Minewater) geothermal heat which the SSLEP is moving forward on.

If the technology of Minewater Geothermal could be moved forward it would enable other flooded ex-mining areas in the UK to be exploited for heat and also the prospect of it having an export potential. Thus, developing a supply chain opportunity which would sit well in the SSLEP due to the professional mining expertise present in its area.

4.7.3 - Deep Geothermal Heat

Also, gained from the minewater temperature heat contours, from analysing and correlating the mine records, indicates that deep geothermal potential at depths below the coal measures at depths of 2.5km to 4.0km is another energy opportunity. Stoke-on-Trent is known to be situated on a geological hot spot relating to the extinct Apedale volcano that sits between NE Stoke-on-Trent and Crewe as recorded by the BGS in 2011, see Figure 42 for this and other geological hotspots in England.

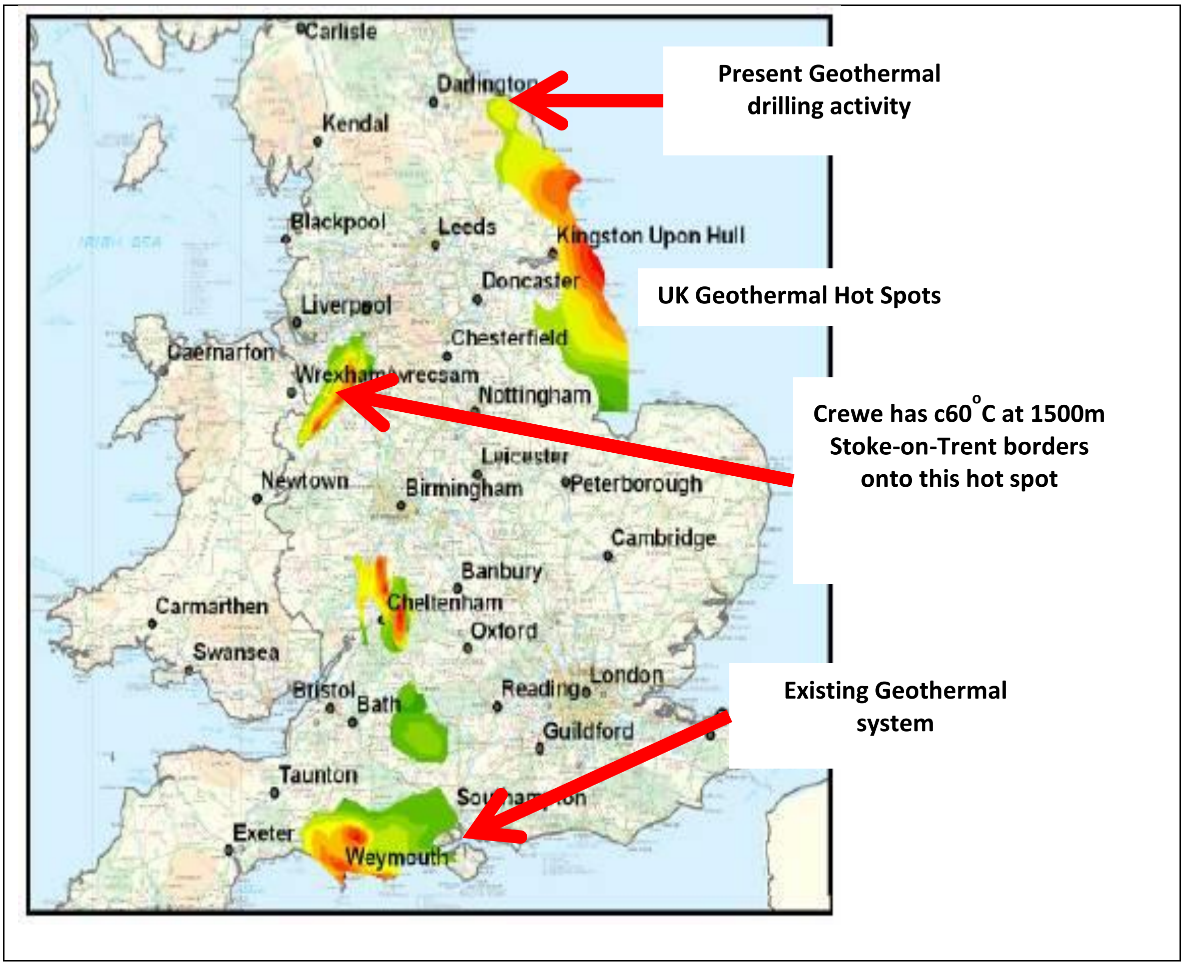


Figure 42: Geothermal Hotspots in England (BGS Hotspot England, 2011)

The regulatory position on exploiting geothermal energy is unclear as it is in an unlicensed position. Whilst it will be subject as any development to Planning and Environmental Impact Assessment requirements, there is no specific geothermal license position from DECC (now BEIS) or the Coal Authority. But the Coal Authority would still need to give permission for borehole activity through mineral/coal measures to assess and exploit geothermal areas of interest.

As previously stated plans to create one of the UK's biggest low-carbon local heat networks in Stoke-on-Trent have moved a step closer to fruition after ministers approved the outline business case for the scheme. The project has two sides one to deliver the district heat network and secondly to power the network through accessing deep geothermal heat.

The Department for Communities and Local Government in March 2015 released £19.75m in capital funding towards the cost of the project to enable Stoke-on-Trent City Council to build the core spine 17-km pipeline. The aims of the project are to reduce carbon emissions, provide protection from energy market pricing instability, attract inward investment and grow businesses by offering access to local renewable and affordable heat.

Stoke-on-Trent City Council has now begun work on the final business case prior to going out to tender for the DHN delivery in late 2017. The city council plans to work with private sector partners, who will bring additional investment to provide access to the heat, which could either be a deep geothermal source underground, or an alternative source such as the city's existing waste to energy plant.

David Frost, chairman of the Stoke-on-Trent and Staffordshire LEP in its Annual Report of 2015, said:

> "The district heat network is one of the most innovative projects the LEP has ever been involved with and the most advanced scheme of its kind anywhere in the UK. The availability of cost-effective, low-carbon heat and the certainty this will offer in terms of future overhead costs will play an important role in attracting more businesses to the city. The government's decision to approve the funding for the (DHN) pipeline is an important endorsement of the work that has gone into developing this exciting proposal and we look forward to working with the city council and the private sector to bring it to fruition".

To support the bid for the DHN to have a prime heat source from a deep geothermal drill, Stoke-on-Trent City Council through 2013 into 2016 has undertaken progressively more detailed geotechnical and financial studies for a deep geothermal heat exploitation. This cumulated in early 2016 by a series of physical geotechnical surface studies utilising an ultrasound based "Vibroseis" technique across two

West East axis lines of 10km each across the centre of the city centred on the proposed borehole drill site on Festival park. The geo-sensing equipment is shown in Figure 43, the same approach as in the GRAME project in Munich, and the two 10km lines are shown in Figure 44.

Figure 43: SoT "Vibroseis" Deep geo-sensing truck

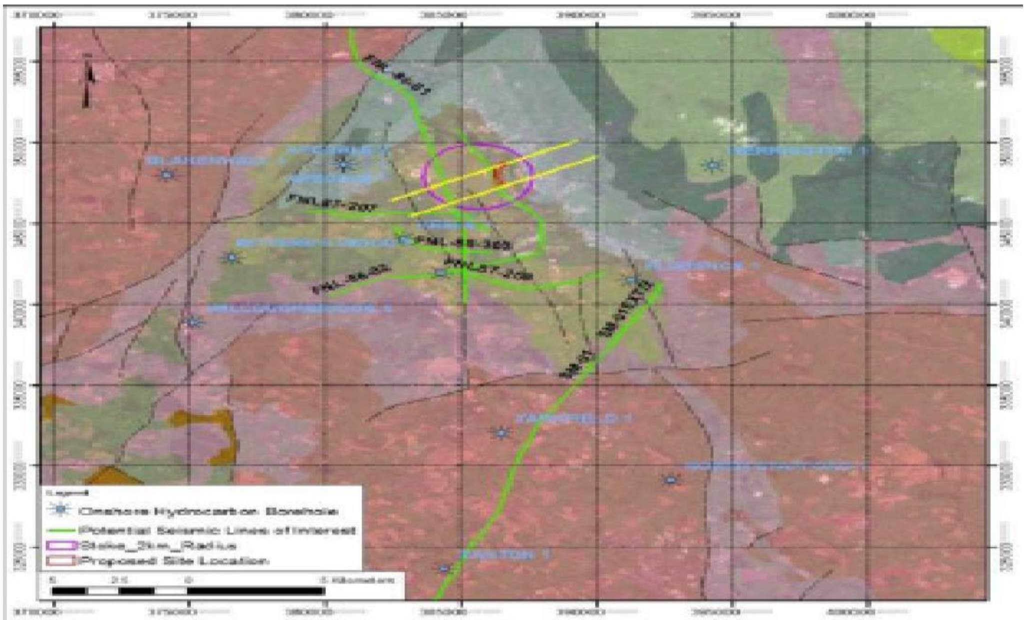


Figure 44: SoT CC 2 x 10km Geotechnical seismic study lines

The drill site would be on the planned DHN line, and is presently sited on the Festival Park site which would give a geothermal borehole a clear access route through unworked coal seams; this surface area was once part of the Shelton Bar steelworks so was never allowed to be under worked. GT Energy are the identified partner to undertake the deep geothermal drill and heat supply – GT Energy have a portfolio of geothermal developments underway in the UK including the Manchester Oxford Road project.

The Stoke deep geothermal project is for heat extraction from an identified aquifer heat zone at a depth of 2.5 to 3.5km under the Etruria valley area. The plan is to drill two boreholes from the Festival Park site one in a north-west direction towards Bradwell and the second in a south-east direction towards Basford to give a horizontal separation between the extraction and injection sites.

The horizontal separation between the bottom of the two boreholes is planned to be around 2,000m (2km), this will allow a high level of security from "sterilisation" of the aquifer in that area. This is due to the extraction of hot water, and injection of cold post heat exchanger water being far enough away from each other that they do not start to affect each other and freeze out the volume.

A schematic of the deep geothermal approach proposed is shown in Figure 45.

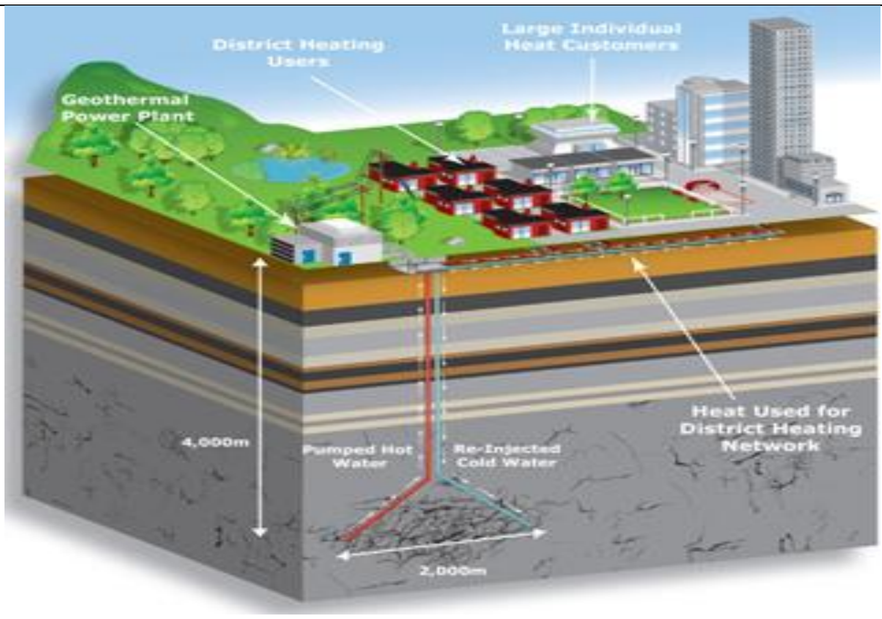


Figure 45: Geothermal approach proposed for Stoke-on-Trent DHN project. REA 2015

There are numerous non-UK examples of deep geothermal power both for heat and electricity generation in operation around the world. Professor P. L Younger of Glasgow University in 2016 in his Energy Institute paper on Deep Geothermal energy for the UK: experiences in Northern England and prospects in Scotland discussed and contrasted the UK geothermal state with that of Iceland, South America, and closer to the UK in terms of geology Paris. The study for the Energy Institute explains how deep geothermal energy has two main uses: Direct use and Indirect use

- Direct use
    - for space heating as planned for Stoke,
    - for cooling, for industrial heating and low temperature processing.
    - the production of drinking water,
    - agricultural uses in greenhouses, fish farming
    - recreational use – spas / swimming pools
- Indirect use – electrical power generation if the temperature is >100°C

He describes how Paris has had around twenty deep geothermal systems operating successfully since the mid-1970s, with other projects now underway in the Paris basin area. Figure 46 gives an example of a working system that has been providing space and water heating for 4,000 apartments in the Creil area in northern Paris since 1976, extracting heat from Chalk aquifers at depths of 1.5km to 2km below the city area.

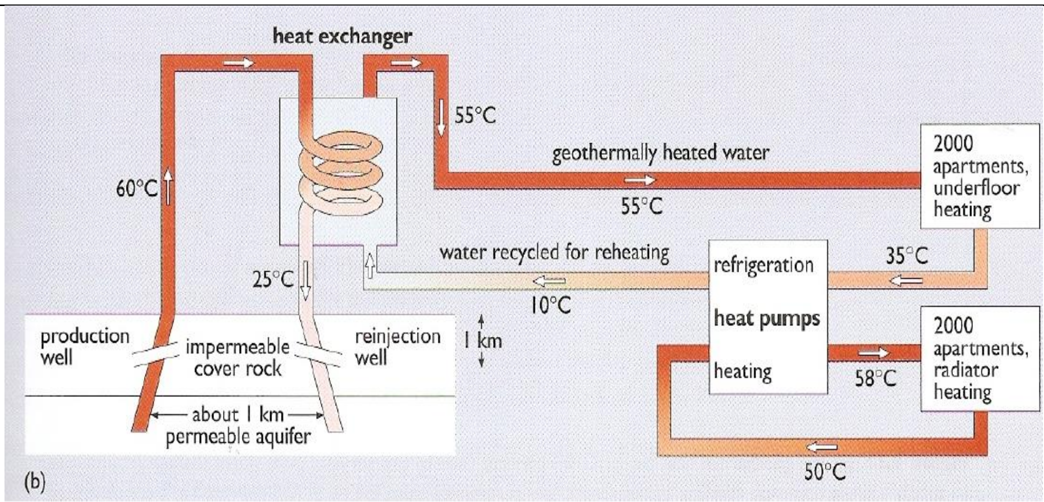


Figure 46: Paris Geothermal system heating apartments. Prof. PL Younger, Glasgow University

Stoke-on-Trent is planning to drill deeper than in Paris, as this is required to access the aquifer heat zone below the coal measures of the North Staffordshire coalfield that extend from the surface to around 1.2 to 1.5km km depth under the city. Below the coal measures lies the Triassic sandstone system in which the aquifer system lies this is described in the DECC Promote study of unconventional gas reserves of 2010, and also as outlined in the Strategic Stone Study carried out by English Heritage in 2012.

At the intended depth for the boreholes in Stoke-on-Trent the geological surveys are indicating a temperature of +90°C; this is excellent and offers the opportunity to supply heat for the DHN and also if over 90°C, and in the region of and over 100°C, the potential for electrical power generation to be considered at a later date.

4.7.4 - Industrial Waste Heat

An area that offers great untapped opportunity is accessing and utilising Industrial Waste Heat which is emitted as a waste "by product" by a range of industrial and service sectors. Many industrial processes, even in the developed, world emit large volumes of waste heat and therefore energy from their normal business activities.

Modelling studies by McKenna & Norman (2010) have identified that technically recoverable waste heat of around 10 to 20 TWh pa is available from UK industrial sites which include the UK NAP (National Allocation Plan) for emission levels by site, which can indicate heat generation levels in EU-ETS PIII (EU Emissions Trading System). This modelling shows that industrial sites with waste heat could be considered but often large heat sources where not close to the heat demand and complex distant DHN schemes would need to be considered to transport the heat, further to this modelling analysis has been carried out to cross match major industrial heat sources (hotspots) which sit on 30km radius from heat demands (sinks) such as cities and towns.

Material processing in many sectors requires thermal activity which normally consists of using Natural

Gas as an energy supply to be combusted to produce heat; process often require energy to both heat and cool materials to gain the required finished product specification. This is true when considering metal, glass, ceramic, plastic processing – often with high temperatures being employed.

Hammond et al. (2014) have analysed a range of vectors or approaches for the use of this waste heat including reuse at lower temperatures, electricity production, upgrading for use at higher temperatures, provision of chilling, and transportation to other industrial sites. The possibility of using the heat to supply DHNs is of great interest in the context of Stoke-on-Trent with its active Ceramic industry. Opportunities for the capture and local use of waste heat from kilns and product dryer systems is worthy of research aligned with future DHN growth.

These alternative uses for the waste heat which have been analysed by Hammond and Norman (2014) were not studied in more detailed study. Their research focusses on the feasibility of using the waste heat in DHNs that supply space heating and personal hygiene hot water. This feasibility is assessed by analysing the extent to which the heat demands, and supplies are compatible. The relatively large heat demand which might be connected to DHNs presents the possibility that most of the heat rejected by industry could be used to supply DHNs, but this potential would be limited by the consideration of several criteria. The criteria which are considered here are: the distance between the heat sources and demands, the heat density of the demands, the heat losses that may occur, the temporal profile of heat demands and the potential use of heat pumps to downgrade high temperature heat.

Heat demand data was made available by the DS4DS project (Taylor et al., 2014). The (DS4DS) project, disaggregated scenarios for demand studies is a £120k UK Energy Research Centre funded project undertaken by a team at Loughborough University sponsored by the UK Energy Research Centre, funded by NERC. The DS4DS project generated 1km x 1km grid square maps of current and future energy demands across Great Britain for five energy categories: domestic non-heating electricity, domestic heating, non-domestic non-heating electricity, non-domestic heating and domestic home-based transport. The heat demand dataset included heat demand from commercial and domestic buildings across the UK at a 1 km2 spatial resolution (over 280,000 data points). Spatially disaggregated energy demand scenarios were developed across the UK from the present day to 2050 to enhance knowledge of the future demands of energy and energy services at the local scale, providing the academic community and government with new capability to deliver on the UK's long-term energy and carbon reduction targets.

Both domestic and non-domestic space heating and personal hygiene hot water demands were included in the analysis. It was assumed that heat networks would be built in areas where they were feasible which was defined as areas with heat demand densities in excess of the criteria, only domestic heat demands as sinks were considered, options for industrial process heat demands were not covered. The resulting Heat Source vs Heat Demand mapping for Britain is shown in Figure 47.

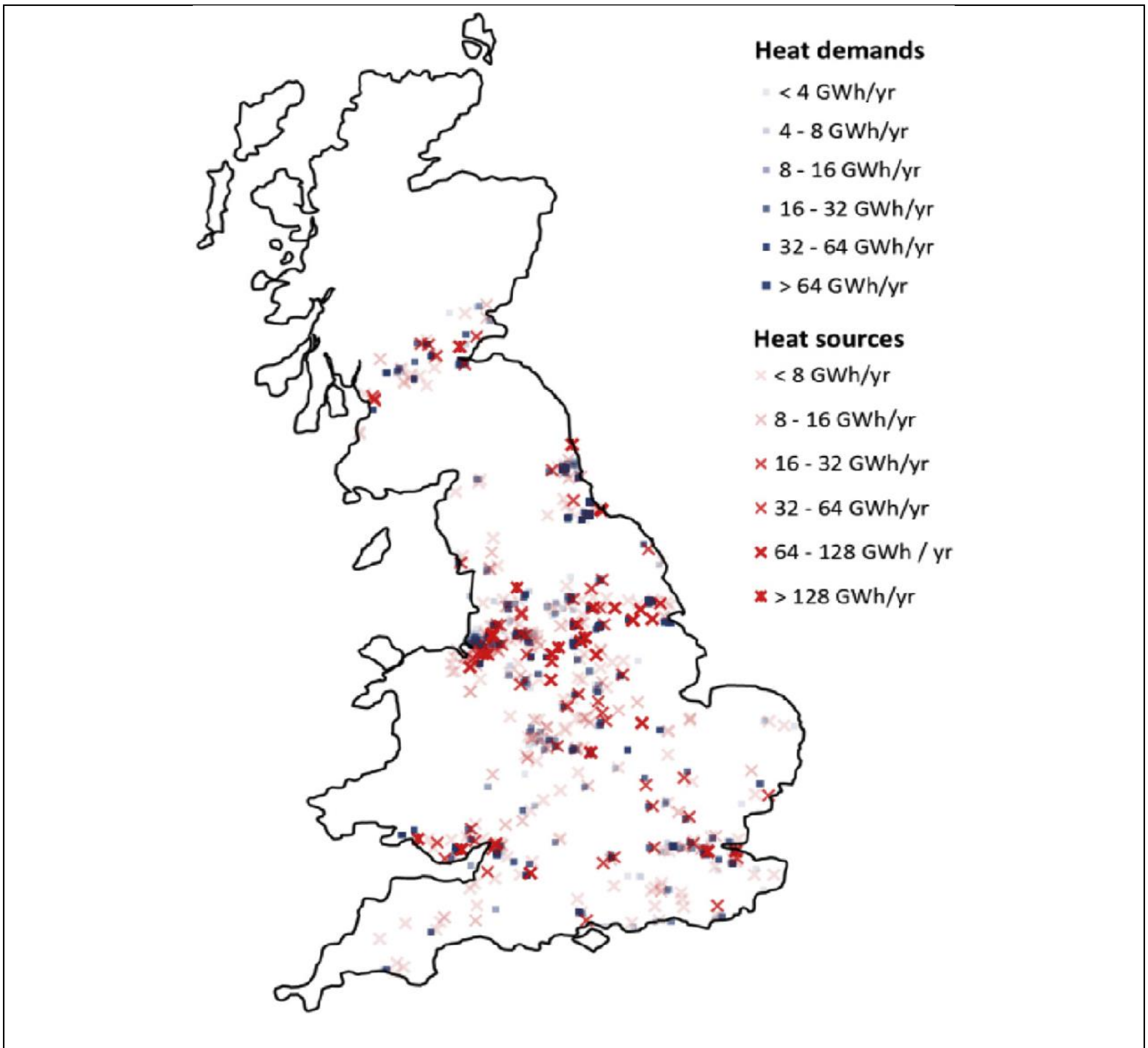
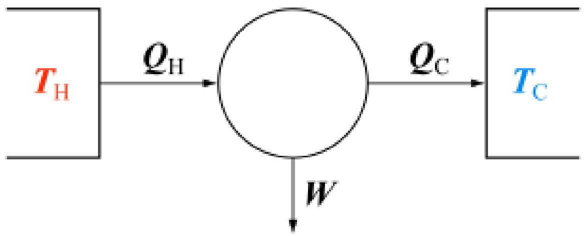


Figure 47: DS4DS Project Heat demands and sources in Britain (connection criteria 3MW/km2 on a 32km range criteria)

Due to the historically low fuel prices, since 1945 until today's price hike, situations have occurred including the early 1970s industry whereby technologies were utilised that have little or no integration of heat capture and the ability of energy reuse as part of the system. This is because it was cheaper to burn and waste, than burn and re-use (DECC Delivering UK Energy Investment, 2014). Now with GHG emission implications and the long-term energy price gradient will rise, accepting present politically driven price instability with the OPEC oil producers attempting to price out shale gas developments to retain market share and thus longer-term price control will happen.

There is an opportunity to pick up "old" technologies to utilise these waste heat sources, as it was done in the past. If we have a waste heat system where a delta T change in the exhaust flow can be obtained as in Figure 48 as W, this can be the input into an Organic Rankine Cycle, ORC system based on the Carnot Cycle as shown in Figure 49, from which work either as rotary motion for physical power or electrical generation can be produced as an output.



Where:

W is the work done by the system (energy exiting the system as work),

Q_H is the heat put into the system from the hot reservoir,

Q_C is the heat leaving the system to the cold reservoir,

T_C is the absolute temperature of the cold reservoir,

T_H is the absolute temperature of the hot reservoir.

Figure 48: The Carnot Cycle

Waste heat recovery is one of the most important development fields for the Organic Rankine Cycle, ORC systems. The ORC technology can be applied to heat and power plants for example from a small-scale cogeneration plant on a domestic water heater, or to large scale industrial and farming processes such as organic product fermentation such as brewing, hot exhausts flows from ovens or furnaces e.g. lime, cement, ceramic kilns, continuous flow glass melt plant, flue-gas condensation, inter-cooling of a compressor, condenser of a power cycle.

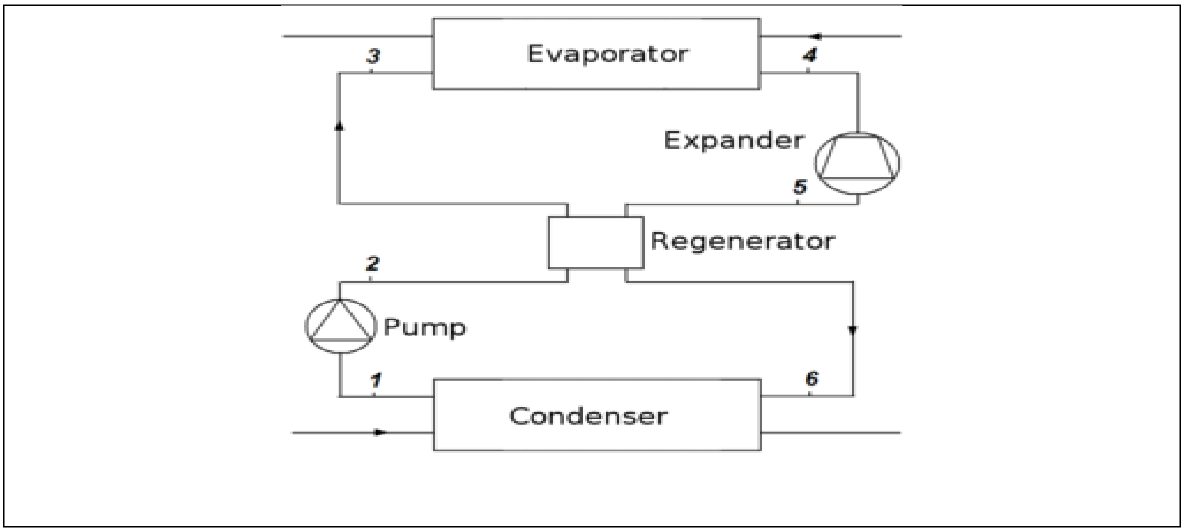


Figure 49: Baseline Organic Rankine Cycle ORC system based on Carnot Cycle

In the ORC system as shown in Figure 49 preceding the evaporator is the heat exchanger acting in the waste heat flow to enable heat transfer into the ORC system, the expander is a simple turbine which if linked to a generator will produce electrical power.

In this system, the cycle is improved using a regenerator: as shown between the evaporator and the condenser since if the heat carrying medium has not reached the two-phase state at the end of the expansion, its temperature at this point is higher than the condensing temperature. This higher temperature fluid can be used to preheat the liquid before it enters the evaporator.

A counter-current heat exchanger (gas to liquid) is thus installed between the expander outlet and the evaporator inlet. The power required from the heat source is therefore reduced and the efficiency is increased.

Opportunities in the UK and global are great for developing and deploying this technology both from micro systems for integration into residential boilers systems to large industrial scale for fitment to power plant exhausts and even to geothermal drill systems where you can obtain an input temperature over 100°C. Such systems are now available commercially. An example of such an already deployed system is produced by ORMAT in Israel in their OEC offer as shown in Figure 50 as a schematic and Figure 51 as applied to a Geothermal situation in Nevada USA.

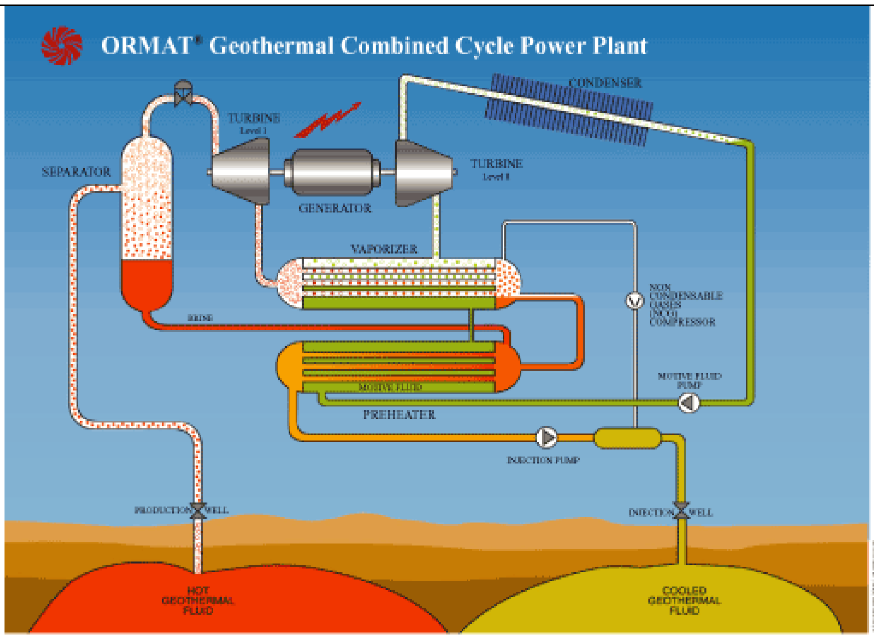


Figure 50: Schematic of ORMAT ORC Geothermal system

Figure 51: ORMAT ORC Geothermal System in Nevada, USA

Ceramic kiln systems will present exhaust with high volume flows in the region of 250°C to 400°C in large volumes from continuous firing systems, thus giving excellent opportunities for stable running conditions. Special consideration would need to be given for heat exchanger materials as often the exhaust flows will be very corrosive and with high levels of dust particles which unless collected in a pre-system will “clog” up the exchanger rapidly and reduce its performance.

4.7.5 - Biomass and Biogas

Research on the potential of Biomass material as feedstock in the UK by Patricia Thornley in her paper “Increasing biomass based power generation in the UK” in 2005, showed the complexity in the UK of the support mechanisms to promote biomass as a fuel that were in place in 2005, with all still in place in the period of this research. Patricia Thorley sees that development lead times for biomass plants are notoriously long compared to other renewable technologies, even for economically viable technologies, as it is viewed that it is necessary that biomass suppliers (farmers / forestry) need at least 4 years of investment risk before a harvestable and thus marketable biomass material is produced to operate plant. She postulates that a biomass development therefore can take from conception to operation at least 6 years.

Wright, Dey and Barmmer in their 2014 research paper state that biomass power is projected to account for approximately half of the new energy production needed to meet the 15% primary energy generation target by 2020 in the UK. This projected target is given in the DECC UK Renewable energy roadmap of 2011, they continue to state that current progress by 2014 has been much slower than required, especially in the case of renewable heat production – which is needed in district heat projects. The level of growth was only a 1% in biomass CHP capacity between 2010 and 2011. One reason put forward for this slow rate of growth is viewed as securing finance for plant build; with the UK finance sector seeing biomass at this time as a higher risk investment than conventional fossil fuelled projects.

The supply cost of biomass fuel is viewed as the main risk factor when considering processed wood chip / pellet as a feedstock. The converse can be said for organic wastes materials where a gate fee of payment can be expected – here the issue is obtaining secure segregated organic waste streams as feedstocks into anaerobic digestion plants which is reliant on Government policy to drive moves to higher segregation of wastes by producers both industrial and residential. The research by Wright, Dey and Brammer (2014) compared feedstock costs in 2010 as being for wood chip a rice of £49.4/tonne with organic material from Municipal Solid Waste (MSW) giving an income level of £36/tonne to be paid by the supplier for disposal.

What is clear from research is that biomass is viewed by Government as a desired fuel feedstock to be utilised in the UK fuel mix as discussed in "Financing the UK power sector: Is the money available" (Blyth, McCarth and Gross, 2015). The UK from their research finds itself in an interesting position as it must greatly expand its renewable capacity, such as biomass and biogas, in the energy mix to meet the EU Renewables Directive (a national legal position to continue after Brexit due to being interlinked into International commitments under Kyoto and Paris climate change agreements). This coincidence of being in an asset investment cycle matching needing to meet strong decarbonisation goals makes the UK an important situation to view the relationship between policies, market structure and investment flows of international significance.

Technically biomass means all plant and animal matter on the Earth. However, in the context of renewable energy, it is convenient to split it into biomass that can be combusted or treated by biological processes. The different types of fuels can be used to produce electricity, heat or fuels for transport purpose. Today it has remerged as a fuel which can be an offset for fossil fuels and here energy from Biomass here is considered in two aspects: -

- Grown crop material feed stock – wood / short rotation coppice (SRC) / miscanthus used in a combustion biomass burner / pyrolysis system,
- Biogas generated Anaerobic Digestion a biological process or via a pyrolysis process,

Both these approaches liberate a methane CH_4 rich gas which can be combusted in conventional spark ignition type engine sets to generate electrical power. Differing biomass organic feedstocks give varying gassing amounts in which the methane CH_4 is in the main balanced with CO_2 and Nitrogen based compounds – as the organic input is viewed as being produced within the last hundred years it is viewed as biogenic Carbon rather than fossil based Carbon – and therefore under UNFCCC (United Nation Framework Convention on Climate Change) protocols and methodologies is viewed as not being a GHG contributor. The UNFCCC rules and methodologies as used for Carbon mitigation calculation in CDM (Clean Development Mechanism) and JI (Joint Implementation) are found under the URL link: https://cdm.unfccc.int/methodologies/index.html.

Whilst the biogas does not have the same calorific values as an oil based fossil fuel or a syngas produced from the gasification of feedstocks which contain oil based plastic materials – it can be viewed as being Carbon neutral which makes it attractive to use to lower GHG emissions.

DEFRA carried a review of Advanced Biological Treatment of Municipal Solid Waste in 2005 to support the take-up of various Anaerobic Digestion technologies to handle MSW organic feedstocks.

Organic materials have been used in Anaerobic Digestion, AD, plants in the water treatment sector in the UK since the 1950's utilising human sewage – but the sector using food and garden wastes (material that is non-cellulous in its cell structure such as wood as it does not break down in the bio microbial AD process) has only started to grow post the year 2000 in the UK. The technology has been established in the food waste sector across the rest of Europe since the mid 1980's so is now well established. The take-up of AD is now underway in the UK as evidenced by the Anaerobic Digestion and Biogas Association (ADBA) mapping of in operational and planned AD facilities that shows some + 125 now in operation handling food wastes as of 2016 (ADBA, 2016). Stoke-on-Trent's sewage waste material is already used to produce power at the Severn Trent Meaford water treatment facility which is based outside the southern perimeter of the city. At this time electrical power is being generated to grid and heat is used within the plant and excess is vented to atmosphere.

As well as biogas production consideration of wood based biomass material as a feedstock to support the Stoke DHN is worthy of review. There are a number of sources of suitable woody biomass material, including waste wood, energy crops, crop residues and forest residues from managed woodlands. The UK does not have large forestry residue resources and most crop residues, such as straw, already have well established markets. Consequently, the UK government is seeking to further the use of purpose grown biomass fuel crops, i.e. Short Rotation Coppice (willow and poplar) and a fast growing perennial C4 grass, Miscanthus sp.

Properly managed biomass resources are renewable and sustainable. When they are growing they absorb CO_2 from the atmosphere and when they are burn it is released back into the atmosphere, thus locking up large amounts of CO_2 in a closed cycle and displacing CO_2 produced from fossil fuels. Burning biomass rather than fossil fuels can also reduce emissions of the gases responsible for acid rain as well as cutting CO_2 emissions.

To assess the feasibility of implementing a biomass fuelled option for Stoke-on-Trent a feedstock resource assessment was carried out by Wardell Armstrong as part of its Renewables Options Study for Stoke-on-Trent City Council in 2008 (Stoke-on-Trent, 2008).

Three different biomass energy resources were considered in 2008; forest residues from managed woodlands, energy crops (Miscanthus and Short Rotational Coppice (SRC) which for the purpose of this study was Willow) and clean waste wood from sawmills and other waste arisings. The resource analysis process examined land in a 40km radius around Stoke-on-Trent’s Civic Centre this was in line with DEFRA biomass utilisation guidelines (DEFRA 2007). The rationale for this was that to receive an energy crop planting grant farmer must have a contract with a powerplant within 40km (DEFRA 2007). Outside this radius the energy costs associated with transporting the fuel to the plant via road become unsustainable. A similar rationale can be applied to the other resource types. Resource estimates are given as dry tonnes equivalent (dte), i.e. if all the moisture was removed from the fuel, to allow a fair comparison of fuels with different moisture contents.

The level of the potential biomass resource is shown in Figure 52.

Feedstock type assessed	Feedstock potential tpa / dte pa	Calorific Value CVn MJ/kg **	Potential Thermal input GWh
Food Waste	5,350 tpa	9.5	14
Forest residues	39,982 dte pa	14.7	163
Energy Crops*	6,442,193 dte pa	12.6	22,548
Wood waste	11,500 dte pa	16.0	51
**40km radius from City centre*		***DUKES UK CVn for fuels 2016*	

Figure 52: Stoke-on-Trent Renewable Options study 2008

It should be noted that the DEFRA advisory 40km radius would in reality be affected by the influence of Manchester in the North and Birmingham in the South – both city conurbations having theoretically their own 40km radius which impinges to the Northern and Southern City's unitary boundaries, so this tonnage would be difficult to secure solely for Stoke-on-Trent use.

Modern combustion technologies are now available so that bio-energy production is clean, efficient and sustainable. Two types of fuel are available for wood fuelled boilers. The larger systems (100kW+) utilise wood chips. Drawbacks with biomass systems are; the need for a reasonable amount space on site for fuel storage (particularly in the case of larger wood chip systems) and/or regular fuel deliveries and the requirement to dispose of the ash generated so creating traffic management issues.

But it is clear there is an opportunity to utilise biomass material both in the form of woody material in combustion systems and, also to produce biogas from Anaerobic Digestion to drive CHP plant to provide power to the grid and heat into a heat network in Stoke-on-Trent.

4.7.6 - Waste Materials

The use of waste materials as a feedstock to generate power and heat is long established in the UK. Both in terms of utilising the waste material in mass burn incinerations plants known as Energy from Waste (EfW) plants where steam is raised to drive turbine generator sets, or from the collection of landfill gas which evolves from decomposition processes when waste is "tipped" into special engineered land based containment systems. The landfill gas is methane rich is then combusted in on site spark ignition gas engine sets generating electrical power sent to the grid.

The use of landfill gas for power and heat is well established, the process of gas production in landfill cells is to a degree "uncontrollable" and is variable due to the organic component in the waste mix, which under the WET Act should minimise the level of organics going to landfill. The UK is now moving away from the use of landfills under the EU Landfill Directive (EU Commission 1999).

Anaerobic digestion is analogous to the landfill gas process other than that it is undertaken in a controlled way as the feedstock is balanced and has been blended to achieve a constant calorific energy value (CVn). Within the SSLEP, Newcastle-under-Lyme Borough Council collect around 3,000 tpa of segregated food waste which is sent to the Lower Reule anaerobic digestion plant in South Staffordshire, as discussed on the Lower Reule Bioenergy Ltd website in 2016. Figure 53 shows a visualisation of a typical Anaerobic Digestion plant layout with reception buildings, digestion tanks and gas tank bubble.

Figure 53: Visualisation of Anaerobic Digestion plant. DEFRA 2005

The Lower Reule plant has a capacity to process 30,000 tonnes of food waste per year and this generates enough electrical energy for 3,500 homes and businesses.

As identified in the Wardell Armstrong renewables option study for SoTCC in 2008 the City has the potential to utilise its segregated food waste material potential through processing by Anaerobic Digestion, this was identified to be around 5,350 tpa. On further research by Wardell Armstrong for SoTCC the physical collection of residential food wastes, as a segregated material, would prove too difficult to achieve across the city due space issues in that the typical housing situation preclude the ability of households to hold the required number of segregation receptacles. Therefore, SoTCC is for the present allowing food wastes to go in with MSW material to the Hanford EfW.

MSW materials in the UK that are not landfilled are processed in the main through Energy from Waste facilities which utilise incineration systems. For incineration the EA expects that the energy value of the feedstock (the CVn) value should be in the range of 10.5 to 12.5 MJ/kg thermal input. This is characterised in the European Commission (EC) Directive 2000/76/EC: The Waste Incineration Directive (WID). This directive forms the background to the regulatory permitting structure around the incineration of waste materials governing the required thermal input parameters into the plants, the pollution limits, the separation approach to the fly ash and bottom ash arising post combustion, and the performance output of generation plant vs the thermal input of feedstock material.

Incineration plants with power generation from MSW feedstocks are termed as Energy from Waste plants (EfW); they are generally large plants designed to handle from 100,000 tpa to 300,000 tpa input of MSW material. In the Stoke and Staffordshire LEP there are two main EfW plants handling the SSLEP MSW and C&I waste material as shown in Figure 54.

Figure 54: SoTCC Hanford EfW and SCC W2R EfW facilities

In Stoke there is an aging EfW at Hanford with a capacity of 210,000 tpa, constructed in 1997, as detailed in its operating WID permit No QP3234SX. The plant presently is designed to generate a nominal 14MW of electricity which is sent to the gird. The plants design however is from an era where the capture and use of generated heat was not considered, therefore some 30MWth of heat energy being generated is presently vented to atmosphere.

This gives a good opportunity for future integration into a heat network in Stoke and to this end the heat network pipe system is planned to come within c500m of the EfW site. As the plant was built in 1997, it is due for replacement in the early 2020's, so a decision on the cost effectiveness of installing heat extraction plant maybe subjective.

Stoke-on-Trent City Council is now preparing its outline for a new EfW plant to replace Hanford and it will be designed to be fully integrated into a heat network system. It could be feasible to continue the operation of the present Hanford EfW with some updating works and for it be operated by a private operator as a "commercial risk" plant offering a service to bring waste materials external to the local area for the purposes of power and heat generation and for the City Council to procure a modern EfW to handle its own generated waste again for power and heat and to be integrated into the DHN by design.

More recently Staffordshire County Council procured a new EfW facility built and operated by Veolia at Four Ashes in South Staffordshire, which came into use in 2014 after a lengthy 6-year procurement cycle. This plant produces 23MW of electrical power, as from Veolia Four Ashes EfW W2R website 2015, but like the Stoke Hanford facility it vents all its heat energy. Discussions took place throughout its procurement process with potential stakeholders between the SSLEP, SCC, DECC and the Department of Welfare and Pensions (DWP) representing nearby prisons facilities to the proposed and now built EfW plant. Unfortunately, this resulted at that time (2011-2012) in no interest in utilising the waste heat as from SSLEP February 2013 Board Open minutes. This potential is still being discussed at the time of this studies completion.

4.7.7 - District Heat Networks

District Heat Networks, whilst not heat generators, are as equally important as they act as the heat delivery systems into which a range of heat generators can feed, from a conventional fossil fuelled system, such as gas fired boilers or combined cycle turbine with a heat take-off to the, as already described, unconventional heat generation sources as coal asset related CBM/AMM, minewater heat, deep geothermal, biomass, industrial waste heat.

A move to District Heating Networks (DHN) is suggested as a potential major enabler in the process of de-carbonising the provision of space heating (DECC, 2013). As of 2013 there were around 2000 networks serving approximately 200,000 dwellings in the UK, meeting just under 2% or 10 TWh/yr of all (domestic and non-domestic) space heating demands (DECC, 2013).

Analysis by Poyry Energy (Davies, 2009) suggested that despite the relatively modest uptake of DHNs to date, “that 4.4 to 6.5 million dwellings and 15.8 to 20.7 TWh/yr of non-domestic space heating demand could be supplied by DHNs in the UK based on a 6% financial rate of return”. Poyry Energy found capital costs to be the main driver of cost competitiveness, this is in-line with UK Government’s view and hence its intention through the Stoke-on-Trent DHN project to demonstrate how to financially de-risk deployment to a level that is acceptable to markets.

The typical heat demand density which they found to correspond to the cost-effective development of DHNs was 3 MW/km2. Subsequent modelling by DECC (2014), which used this heat density as the criteria for DHNs concluded that 20% of domestic heat demand is suitable for connection to DHNs. Equivalent analysis of data supplied by Spatial mapping of building energy demand in the UK, (Global Change Biol, 2014), suggested a similar result (18.6% of total space heating and hot water demand, around 63 TWh/yr).

The UK does have a few Heat Networks in operation some are quite large being built over the last 20 to 30 years, examples being operated by a Vital Energi a key UK commercial operator in:

- Nottingham,
- Sheffield
- BAA Heathrow Airport
- Lerwick

Nottingham

The DHN in Nottingham has been operating for over 30 years and is one of the largest in the UK. Enviroenergy Ltd is the Energy Supply Co, ESCO that operates the system today – it was originally manged by British Coal, the network has its heat produced at the Eastcroft Energy from Waste plant and provides hot water, steam and electricity to a customer base across the city centre.

- Network size 85km
- 5,000 domestic and 100 commercial customers
- 27,000 Tonnes CO2 mitigated against fossil fuelled emissions
- Contract value £24 million – 1989 – to present

Specific Heat Network information is from URL reference as of November 2016

https://www.vitalenergi.co.uk/casestudies/nottingham-city/

Sheffield Heat Network

The Sheffield system is an excellent example of how a network system has continued to expand by phases. The first phase saw a partnership venture established in 1987 between Sheffield City Council and Sheffield Heat and Power Ltd (private sector). Its base aim was very much aligned with the present drive by central Government – to provide a range of public and private sector customers with reliable, secure cost effective locally generated low carbon energy source. More recently the operation is now operated and owned as a subsidiary of Veolia – Vital Energi. The system is the powered by the city's energy from waste incinerator at Bernard Road. This burns around 120,000 tonnes pa of MSW producing 60MW of thermal energy and 19MW of electrical energy – enough for 19,000 homes. The steam that is taken from the system via heat exchangers and raises water to a high temperature water which is distributed through a community energy network.

- Network size over 50km
- 2,800 domestic and 140 public and commercial customers
- 21,000 Tonnes CO2 mitigated against fossil fuelled emissions
- Contract value £16 million – 1987 to present

Specific Heat Network information is from URL reference as of November 2016

https://www.vitalenergi.co.uk/casestudies/sheffield-city-district-heating/

BAA Heathrow Airport

As part of the £4.3 Billion investment in the new Terminal T5 it was identified there was potential surplus heat available from an existing Combined Heat and Power (CHP) system housed in the World Cargo Energy Centre, this was then incorporated in the T5 development. Today the CHP surplus heat provides around 80% of T5s heat demand through integration into the T5 Energy Centre and gives 10,877 Tonnes pa of CO2 mitigated against fossil fuelled emissions. This project shows how it was feasible to integrate an existing CHP system that had surplus heat that was being wasted by being vented to atmosphere.

- Network contract value £3.3 million – Nov 2005 – June 2006.

Specific Heat Network information is from URL reference as of November 2016 https://www.vitalenergi.co.uk/casestudies/baa-heathrow-airport/

Lerwick District Heating Scheme

This scheme is of great interest as it demonstrates that it can be economically viable to have a large network with a pipe length of some 30km feeding a relatively small building stock. The system has its heat provided by the Shetland Heat & Power Waste to Energy plant which also supplys electrical power around 8,000 of Shetlands' inhabitants.

- Network over 30km
- 7,800 Tonnes CO2 mitigated against fossil fuelled emissions
- The Energy from Waste plant serves 8,000 inhabitants
- Contract value for system £6.5 million – Apr 2008

Specific Heat Network information is from URL reference as of November 2016

https://www.vitalenergi.co.uk/casestudies/lerwick-district-heating-scheme/

In addition to these large networks there are a number of smaller networks running in a number of towns and cities in the UK – these are often nameless and difficult to identify in national statistics, they form part of new building developments which incorporate a small CHP plant and it is sized to provide heat to its own building and also to a close ring around the building (DECC, 2013).

The technology of DHN's is well established outside the UK – as already discussed Sweden and Denmark have a very high take-up with the cities of Copenhagen and Stockholm running at around 90% of their heat supplied by a network system. Sweden is viewed at an overall 55% supply of its national heat by networks with very little growth potential other than incremental amounts now (Åberg et al, 2016).

Most of these systems in Scandinavia have been in operation now for over 30 years with some elements of the pipe system now at 50 years and nearing its original design life. This makes the UK and Eastern Europe of great interest with the UK moving to a new network build situation and with Eastern Europe in the ex-Soviet countries with old communist build inefficient systems that need upgrading or replacing. So, we have a major market opportunity of new build in the UK and system replacement which will be with new state of the art systems – much of it will be smart digital technology - hence the Swedish Energy Agency wishes to engage to have a two-way partnership offering their 50-year operational experience in exchange to be part of the new innovative system design and build out to take back to be incorporated in the replacement cycle in Sweden. This Swedish Energy Agency partnering is being led by a consortium approach of Scandinavian supply chain entities including pipe and valve companies, design and engineering consultancies to large municipal operator companies.

Therefore, we can see that there is enormous potential for economic regeneration to be achieved by the promoting the opportunity for supply chain growth and diversification into the UK Decentralised Energy market as presented by the pipeline of projects for District Heat Network build out and for the provision of power generation in terms of heat supply into systems as a direct output or as a secondary to electrical generation.

To support this DECC created after the release of its 2012 Heat Strategy study the HNDU – Heat Network Delivery Unit which acts as a National promotor of Heat Network development. Since its creation in 2013 it has handled a number of funding programmes initially for local authorities to use for opportunity and pre-feasibility studies for the potential of a DHN in their jurisdiction. Further funding was made available in 2014-15 for local authorities to take their studies further and develop into full feasibility studies with which to obtain outline costings and possible routings for pipework, heat mapping, anchor tenant identification.

In the late summer of 2016, HNDU was awarded a further £300 million to support the next stage of LA DHN development – to act a leverage funding for applicant DHN projects to work up a balancing private sector finance and then to move projects through tendering into build out. The £300 million public funding is aimed to lever up to £2 billion private funding.

With DECC now part of the new Department of Business Energy and Industrial Strategy (BEIS) HNDU is also now considering the issue of project promotion and to aid decentralised energy and DHN supply chain support. As part of this working with the Swedish DHN procurement agency VARMEK the UK equivalent is being developed under the auspices of the Greater Manchester Combined Authority called the District Energy Procurement Agency (DEPA). DEPA is yet to be launched as of the summer 2016 but its basis is to develop a framework of procurement procedures available for English and Welsh local authorities. DEPA working with HNDU has identified the key building blocks of the supply chain and skill sets needed for DE and DHN development. It allows a hierarchy of development areas required to prosecute DHN projects this is shown in Figure 55.

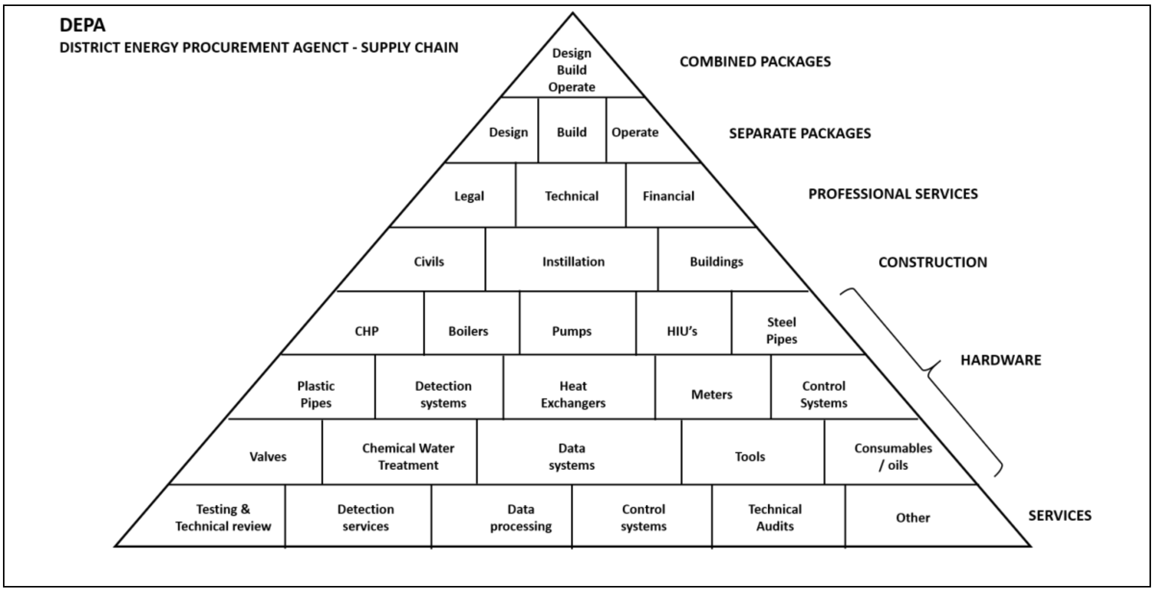


Figure 55: DEPA DHN Hierarchy of project framework areas (DEPA, 2016)

The DEPA Framework structure consists of conventional services and hardware and innovative SMART systems. It is focusing on giving local authorities access to skill sets that will support tender and procurement development from a UK standardised viewpoint. The framework will validate suppliers' hardware and service offers this will therefore assist in identifying missing parts to the DHN / decentralised energy jigsaw that makes up the supply chain which is crucially important.

The missing parts of the jigsaw supply chain will be areas for hardware and/or services – and also crucially for skill gaps. This will allow a gap analysis to be undertaken and then by utilising other tools to remedy the shortfall both in totally missing services or lack of capacity. This would educate national and regional programmes to target commercial entities for "planned" diversification giving as required appropriate support for training for skills, finance, premises, business process re-engineering. This looks like a planned economy approach – but it would likely be required to get the commercial sectors re-orientated to move forward.

4.8 - SMART Networks

A key investment area that would be an enabler for decentralised energy is the deployment of smart systems, also known as digital energy. The public face of smart systems (smart grids / networks) is the deployment of individual smart meters which has a government driven national rollout to be in the period 2012 to 2020. Over this period, UK Government sees 53 million smart gas and electricity meter installations to be undertaken – which is detailed as a £7.5 Billion capital investment (DECC, 2014).

Having smart meters in domestic and non-domestic buildings introduces the potential for access to large volumes of operational data that could be gathered to make and drive investment decisions by both the private and public sector. This acts as an enabler for large to small scale power generators and distributers such as from the big six power companies (Eon, SSE, National Power etc) to the community ESCO's being able to approach the finance markets for investment based on operational data rather than growth assumptions. The UK Energy Investment paper points to the UK Government's 2012 Interactive Heat Map that shows heat demand profiles across the country. It assists investors to identify potential opportunities for heat network investments (DECC National Heat Map 2012 URL http://csembaa1.miniserver.com/index.html#).

The National Heat Map was commissioned by the Department of Energy and Climate Change and created by The Centre for Sustainable Energy based in Bristol (https://www.cse.org.uk/). The purpose of the map is to support planning and deployment of local low-carbon energy projects in England. It aims to achieve this by providing publicly accessible web-based maps of heat demand by area.

The heat map is primarily intended to help identify locations where heat distribution is most likely to be beneficial and economic. The heat map is quite coarse in its level of detail so is not a tool for designing heat networks directly it acts as a visual guide for potential placement. With the exception of public buildings, the heat map was produced entirely without access to the meter readings or energy bills of individual premises. This means that once a location has been established as having potential, it will always be necessary to obtain directly metered data on the relevant sites.

The concept, and potential first use, of the Heat Map follows on with the approach as established with the DECC supported web based national wind speed maps. These maps assist with wind turbine site identification and the EU PVGIS web based tool which gives levels of solar incidence down to a postcode level for differing roof orientations. This therefore allows a rough indication of solar power relating to a domestic panel installation to a multi-megawatt solar farm to then support more detailed feasibility study.

The DECC Heat Map has also been expanded to give information relating to water resources with heat capacity levels for water source heat potentials from coastal, estuary, canals and rivers. Again, this is to give a site opportunity view, with the Environment Agency and other regulatory bodies requiring a specific site detailed local assessment model to undertaken accompanying any planning and permitting development application.

An example of a water based Decentralised Energy network system is the Kingston Heights development on the riverbank in Kingston upon Thames in East London. CIBSE, the Chartered Institution of Building Services Engineers, heralded the Kingston Heights project as a ‘working at size prototype’ for a low cost renewable energy system based on heat transfer from rivers and other water bodies in their January 2014 CIBSE Journal article by Alex White (2014).

The development assesses intakes from the Thames river water through heat exchangers into a heat pump system that via a buffer tank delivers under floor heating and hot water into 56 affordable homes, 81 private apartments, and into a 145-bed hotel. The intakes of the system sit 2.5m below the surface of the river Thames, where the water temperature is relatively constant all year round.

The abstracted river water passes through a two-stage filtration process, heat is transferred from the river water to a secondary circuit that links to a plant room on the fifth floor in the apartment block. Water source heat pumps then increase the temperature of the low-grade heat before sending it to mini plant rooms, where the second part of the heat pump upgrades temperatures further. The system is capable of delivering 2.3MW of heat.

The most innovative element of the scheme is the taking of such a high thermal load from an open body of water. This approach with direct interchange with a large water body, in this case the River Thames, gives far higher load potential than a traditional open loop borehole system, where the abstraction rate on groundwater is limited to how much can be pulled physically without causing instability to aquifer temperatures. The development shows what is possible when developers include options in their developments that utilise low carbon localised geo-resources. Whilst this project is viewed as a first for its size in the UK it is not unique outside the UK; the project technology of water heat transfer is not widespread as of yet in 2015 – so this does offer potential for supply chain diversification and an economic regeneration driver if it was to become more widespread.

The smart network approach is now viewed by the UK Energy Investment paper as the next logical step. Building on the hardware infrastructure investments including smart technology and the use of cloud computing will allow decentralised energy to be deployed with efficient network integration of both renewable and conventional energy resources on the distribution level.

To kick start applied smart solutions the city of Manchester is taking part in an EU ERDF project called Triangulum running from 2015 through into 2019. Manchester is working with the cities of Stavanger in Norway and Eindhoven in the Netherlands as the initial “Lighthouse Cities” with “Follower Cities” Leipzig in Germany, Sabadell in Spain, Prague in the Czech Republic and very interestingly Tianjin in China (as an observer city).

Triangulum has 22 partners has a range of local authorities, universities and private sector partners who bring software platforms and hardware solutions into the project which is an ERDF project managed principally by Fraunhofer IAO (2015). The Lighthouse Cities will act as catalysts for exploitation and replication through a Smart City Framework that is based on the ongoing evaluation of smart city implementations in those Cities which heavily draws on the Strategic Implementation Plan of the European Innovation Partnership on Smart Cities and Communities.

The "Smart City Framework" here refers to a guideline and decision-making toolset that helps Follower Cities and other interested cities to replicate smart city solutions based on local factors and functioning modules of integrated technologies (energy, transport, ICT), business models and stakeholder structures. Two main elements of the Framework approach work to combine individual aspects of city how its own "peculiarities" or "uniqueness" are accommodated in the smart city modules so that:

a) The assessment tool containing a set of "smart" city indicators that define a checklist of important key action fields for smart city development and methodology which the identifies the best "local" starting points for the implementation plan to move to Smart City.

b) To give guidelines detailing project developments for functioning smart city modules which give integrated technologies for energy, transport, ICT, stakeholders and, for business models;

These two steps "a" and "b" need to integrate into each other; crucially regarding the business model which also covers aspects of local supply chains to be in the design, development and deployment phases. This allows the city economic development side to engage with supply chain development and drive business diversification to obtain where possible localised spend, this then links into Economic regeneration which is key.

Smart network technology is key to the continued deployment of renewable low carbon energy generation, these new sources are gaining ground worldwide and making up an increasing proportion of the UK generation mix. This is set to continue to meet legally binding targets the UK is aligned to. Therefore, with variable renewables such as wind and solar which are continually changing due to season and varying weather conditions a highly complex power matrix mix has replaced the unidirectional, relatively easily manageable energy conversion chain that the UK has seen over the last 50 plus years - operating in the form of the infrastructure the UK is now needing to replace due to it being at the end of its operational design life.

With power generation from renewable sources such as wind and solar being intermittent and at relatively small-scale it is found grid infeed of this power generation takes place at the distribution level. This means for example that a residential home as well consuming power (the old power generation infrastructure model), now it can also be a generation point pushing power into the grid for some of the time and pulling at other times – i.e. continually varying.

So, with increasing multi renewable generation sources the UK distribution system has to change from a one grand system to a multi system – this is both a facilitator and supporter for decentralised energy systems, generation then can both be contributing to the whole but also to localised generation and use. To balance such multi node networks which must both stand alone and interrelate with the other network nodes requires smart systems, cloud platforms for mass data collection, transfer, interpretation and action taking systems.

Not only in the UK but also globally existing grids are becoming smart grids with an ability to integrate considerable amounts of distributed generation, handle levels of intermittent power fluctuations, ensure power quality, and enable the reliable and economically efficient supply of increasing power-hungry societies. Therefore, it is essential that grids and networks are modernised and automated as a prerequisite for the future supply reliability.

The supply chain opportunity offered by smart grid technology systems is potentially very large as it relates to not only the UK's Heat Network plans as each of the HNDU 100 plus heat network projects as listed in Appendix I, will incorporate smart grid technologies but also the building infrastructure fabric will incorporate smart monitoring technologies as well.

The IPPR report (IPPR Piping Hot: The opportunity for heat networks in a new industrial strategy) was released in March 2017. As this paper was being written up, details that the UK Committee on Climate Change (UKCCC) has identified three main policy areas that need to be developed to stimulate the low carbon heat sector was released, which were:

- Hydrogen – early work being carried out on this in the Keele University Hydeploy project associated with the Smart Energy Network Demonstrator SEND project.

- Heat pumps – the Keele University SEND project has work packages for heat pump technology development.

- Heat networks – again SEND and the also the Stoke-on-Trent DHN linked with the BEIS DHN project listing show activity but now needs supply chain engagement.

Whilst all the technologies identified above by the UKCCC will be critical to achieving the decarbonisation of the heat sector, heat networks are the shelf ready technology that can be scaled up most quickly and then combined with SMART cloud based platforms that will be able to have the largest impact on reducing carbon emissions.

Considering the BEIS industrial strategy goals to tackle the ageing energy infrastructure issue as discussed, the IPPR report shows the scale of the industrial supply chain opportunity for smart heat networks is compelling with a market value of private investment of £22 Billion and an ability to create some 81,000 new jobs. This aligns with the Stoke and Staffordshire LEP target to create some 5,000-new high level GVA jobs in the smart energy field with a potential share value of £1 billion of the investment spend coming into the SSLEP area in new commercial supply chain diversification in regard to equipment provision / professional service / operational support.

5 - Discussion and Recommendations

Can Decentralised Energy deployment drive Regional Economic Regeneration?

Can Decentralised Energy deployment drive Regional Economic Regeneration and have a leading park in driving economic regeneration in the UK? This question a key component of this research activity.

Consideration of various stakeholders such as regional growth engines such as the Midland Engine, The Northern powerhouse, Local Authorities and the LEPs who represent both public and private groupings must be taken into account in the development and implementation of coherent, integrated and focused support programmes. Such programmes giving targeted support for supply chain growth and aligned skills training to drive decentralised energy deployment to create jobs and also increased levels of GVA which leads to increases in local economies.

Decentralised Energy in the form of smart energy district heating infrastructure could contribute to the UK's energy policy goals of de-carbonisation, renewable energy deployment, tackling fuel poverty and ensuring energy security. However, while a number of DHN schemes have been developed over the last decade, deployment of the technology remains limited. A number of challenges are seen to be significant barriers to the scaling up the deployment of "smart" DHN in the UK.

Whilst district heating networks are inherently local infrastructures, they should be considered to be positioned in regulatory and market contexts organised at larger spatial scales, making geography an important factor and coordination across spatial scales an important policy area for accelerated deployment

The UK has a long and chequered history of attempts to develop district heating networks (DHN) as viewed by Russell (1993). The UK developed a few large-scale Heat Networks in the 1960s and 1970s such as in Sheffield and in Nottingham driven in these cases by local political drivers tied into associated infrastructure build such as from powered by an energy from waste plant into residential developments in Sheffield.

UK Government and the devolved administrations of Scotland and Wales state that accelerated roll out of the technology would contribute to achieving national energy policy goals (DECC, 2012). However, given a history of failed attempts to establish far-reaching DHN programmes in the past, and the small share of DHN in the space and water heating market viewed by Euroheat & Power for the UK at around 2% in-comparison with Denmark's 47% and Sweden's 55%, (Euroheat & Power, 2011); the extent to which DHN will be deployed and also interlinked with smart network application, when viewed on the timescales established by the 2020 carbon and renewable energy targets, is viewed as highly demanding in both supply chain activity and also for upskilling a sizeable nationwide workforce.

This therefore is a policy and programme problem which highlights the principal challenges to the deployment of Decentralised Energy, mainly in the form of district heat and power networks acting as facilitators in the UK.

The technical components of non-Smart DHNs are relatively mature, having been developed over forty years of widespread use in Scandinavia. This is demonstrated by Dyrelund and Stevenson (2004), and by Ericson in a study of the growth of District Heating systems in Sweden (2009) particular in the interlinking of Smart DHN deployment as part of a Decentralised Energy rollout in the distinct physical, social and institutional contexts of the UK presents new challenges requiring innovative organisational, contractual and commercial solutions.

Two features of the UK context are important here:

> ***First,*** while decentralised energy smart DHN are an inherently locally based infrastructure more often limited to high density residential and commercial office areas by financial, rather than physical, constraints, as alluded to by a paper by Roberts (2008). It is nonetheless situated in systems of regulation and government, resource flows and markets which operate at local, regional, national and international scales. The liberalisation and privatisation of the UK energy market have altered the scope for public authorities to both be owner operators and

also as direct developers of energy systems working towards social and environmental goals, and have consolidated existing assets under the control of a small number of companies whose international scope challenges development of locally-specific systems.

Secondly, the role of local government had changed in the period since 1997 and more so since 2010 as a move from "Big Government" as led by Prime Minister Cameron's localism agenda and reducing local governments influence, from service provision to enabling others to provide services as outlined by Bulkeley and Kern in their comparative study on Local Government in the UK and Germany on the governance of Climate change (Bulkeley & Kern, 2006).

In the UK, this move from "Big Government" has led to a proliferation of public and private service providers has reduced the in-house capacities of local authorities to plan, design and/or operate technically and financially viable schemes as discussed by Leach and Percy-Smith (2001) in developments in UK LA Governance models.

This contrasts with the municipal energy companies that developed in Sweden and Denmark in the twentieth century since the 1960s and 1970s as described by Werner, in a review of DHN in Sweden (2010). Whilst the UK has been at the opposite end of this spectrum, with its energy market liberalisation and history of centralised control over local authorities. More recently with the lack of skills for Decentralised Energy and associated DHN development recognised by BIS and DECC in the Government Heat Strategy paper of 2012

This focus on decentralised energy, as it was not directly aligned with an existing or upcoming policy, was initially difficult to support; but it was recognised as a unique ask by the LEP. Back in 2013, no other LEP had a major programme for economic regeneration around energy developments, and so with the issue with future UK energy supply problems figuring in Whitehall new policy developments it won a range of ministerial and department support. Whilst this support was positive it meant that the “ask” was subjected with a lengthy submission and scrutiny process. With no clear policy agenda in place, in this decentralised energy area in the UK, it showed a clear weakness in the assessment methodology in Whitehall – the Departments of DECC / BIS / Treasury and Cabinet Office all could see the potential but did not know how to assess it and move it forward. This has resulted in bureaucratic delays not technology delays in deploying the SSLEP’s energy programme, essentially slowing down the pace for economic regeneration.

To characterise this, we find that it is taking longer to deploy already EU established DHN technology in the UK than the United States took to put a man on the moon in the 1960s.

One key problem was that DECC had a developed policy area around its 2012 Strategic Heat Strategy, but this was aimed at supporting initial pre-feasibility and scoping studies for DHN opportunities by local authorities. The issue for the SSLEP was that this level of initial work had been undertaken a number of years prior so was already in advance of where DECC was starting from – so this created a crisis of direction. The team as set up in Stoke-on-Trent City Council to develop the DHN and associated deep geothermal heat source had no national policy or critical guidance from DECC. In fact, the result was that DECC directed other local authorities to contact the Stoke-on-Trent City Council DHN Team to ask for advice and support as the Stoke-on-Trent DHN team was at the same point if not in front of DECC and BIS on how to conceptualise, develop and deploy a large multi km sized DHN systems.

In terms of carbon reduction, the UK in line with the EU, is legally bound by legislation driven by the Kyoto Protocol. The Waste and Emissions Trading Act of 2003 set up the framework for the UK’s entry into the EU-ETS (European Union Emissions Trading Scheme) which came into being in 2004 and entered its third Phase in 2013. Within the UK the EU-ETS PIII will be a key driver in seeing a carbon price climb as the swing in the scheme moves from a 80% free allocation to a 80% purchase as it moves towards 2020. The European Commission in July 2015 presented a legislative package that would form the basis of EU ETS PIV for the period 2021 to 2030. The key points of the energy debate in the UK is the result of many policy positions and regulatory requirements that can be traced back over many years.

- UK market – large emitters do not utilise the EU ETS as market they see it as a Tax mechanism, in comparison German emitters utilise the EU ETS market taking up now low market value of Carbon EUA for future trade against production growth or for investment funding.
- Lack of realisation of EU intention for EUA base price 2015 15-20 Euros, 2020 35-50 Euros, 2050 200 Euros. If economy not fundamentally changed will effectively make uncompetitive.
- Confusion of recent FIT adjustments / CRC amendments by UK Government sending bad signals to all sectors of market from residential to large investors.

The looming UK Energy generation shortage can be viewed primarily as an outcome of the privatisation drive of the 1980s and 1990s where there was no regulatory requirement on the "private" sector to be legally tied to an ongoing investment cycle to ensure plant life was kept to an average life of 10 years meant virtually nothing was undertaken regarding grid or power station upgrade other than a rush for natural gas fired generation.

In essence, it should be simple to kick start and drive forward the restructuring and rebuilding of the UK's aging power asset sector as there is a large consumer base with a known need. Where it appears to get difficult is in the range policy drivers that seem to conflict or sit on differing timelines which then confuse and alienate the private sector routes to investment and finance as their ROI models have external risk that is difficult to mitigate. How has this conflict of policy come about?

The UK situation regarding obligations to energy developments and switching generation sources is in the main is based on EU policy, legislation and regulatory directives which will still be in place until at least March 2019 considering that the result of Brexit. The EU Energy Roadmap 2050 (URL:

https://www.energy.eu/publications/Energy-Roadmap-2050.pdf) sets and details guidance to how the EU commitment to an 80-95% carbon emission reduction by 2050 has serious implications for our energy system. It sees the need for the generation, distribution and end use to be far more energy efficient. It is aligned to the target that two thirds of our energy should come from renewable sources and electricity production needs to be almost emission-free with a view that there will be higher demand. The energy system has not yet been designed to deal with such challenges, and that by 2050, it must be transformed. The Roadmap postulates that only a new energy model will make the EU system secure, competitive and sustainable in the long-run.

Therefore, under this EU Energy Roadmap the UK finds itself with a dilemma which can be viewed as an opportunity: the dilemma being that the UK generation capacity is overdue a major investment with around 40% of its plants now being decommissioned this is also balanced with the distribution system as in the National Grid for both electricity and natural gas is also nearing 50 years old and is nearing major replacement as it is near the end of its design life.

In addition to the plant and grid replacement situation the UK is also committed to carbon emission reduction targets to reduce the UK greenhouse gas emissions by 80% by 2050 (The UK Climate Change Act, 2008). This brings another dynamic that is driving change as the existing sources of emission give clear pointers to UK Government to focus policy, legislation and support programmes.

There is a need for the UK not only to drive hardware change which gives low carbon energy but also to drive drastic supply chain diversification into an ability to support this move to low carbon generation and for a new culture in innovation and commercialisation of products and services particularly into the energy sector. This need to drive innovation in the low carbon sector is discussed in the research of Uyarra, et al. (2016). The research paper used a policy mix approach to examine the UK's support for innovation in low carbon manufacturing and service sectors considering the impact of governance and institutional issues. Their analysis showed issues in the overall approach – the multi-scalar design and delivery approaches of these policies showing gaps and tensions in the policy mix. Crucially they show that the regional institutional entrepreneurship was fundamentally not engaged in the process of driving change and that there was a lack of coherence and consistency in UK innovation policy towards the shift to low carbon.

This has created uncertainty and hampered private sector investment which is counterproductive for the UK Government which needs major private sector investment. The dilemma for the UK Government is therefore compounded by the fact that the energy sector is viewed as a "private market" and so should be undertaking private investment to replace plant.

So, the UK Government would like to see the market handle and self-finance the replacement process. What the Government has tried to do is create support for re-generation programmes. However, this is being hampered by a loss in regional capacity and institutions to anchor programmes into. Who, due to a reduction in resources, lack the local and regional actors and skill sets to act as leverage in delivering diversification programmes.

This is then reinforced as far as regional / LEP consistency is viewed where there is a lack of a clear standard mandate with differing priorities with a fragmented support structure often relying on part time voluntary LEP private sector Board Directors who find their remits changing or difficult to define as they are subject political changes within local authorities. The LEPs are hampered by following local authority protocols on long drawn out decision making processes, which leads to private sector members confused and feeling disenfranchised as they are used to quick decision making and implementation.

On reviewing and researching the relationship between principal policies and technology options, a fundamental issue in the UK is a lack of supply chain capacity in terms of capability in equipment, knowledge base, skills and no plan for linked training at all levels.

Investigation and observation for this study sees drivers and barriers for a variety of potential decentralised energy and associated smart district heat network technologies and schemes, including their applicability and appropriateness for the UK context.

A variety of recommendations for the encouragement and increased deployment of decentralised technology which would bring a corresponding increase in localised economic regeneration in terms of uplifting GVA in the UK can be developed, these are detailed following. These recommendations are not prioritised or exhaustive, but instead represent a spectrum of thinking and suggestions to be taken as a starting point for pushing forward and enabling solutions on how to increase the potential of various decentralised energy approaches within the UK.

- **Decarbonisation:** the goal of decarbonisation should be installed as a baseline target in all institutions at all levels local to national government. The prevailing values and decision-making processes should be informed by the increasing awareness of institutions and individuals around carbon reductions and enhanced energy efficiency. Systematic and coherent approaches need to be promoted in the decision-making process, led by energy specialists and sustainability champions from public and private institutions, as well as from the communities themselves in which the decentralised energy will be embedded. It is clear that decarbonisation on a local or project level will often meet initial opposition, but it is likely to shift as more information becomes available regarding the benefits, both direct and indirect. In addition, policy should not only alert, but also drive this goal and provide the guidance on the possible means of achieving it.

- **Policy instruments improvements:** a wide variety of interlinked and coordinated policies should be introduced. Policy instruments need to incorporate aspects that deal with equity, efficiency, scientific validity, consensus, frugality and environmental effectiveness as well as considering financial, social, political and legal implications of policy implementation. They should be coherent and integrated with both existing and upcoming new legislation (as is known) to avoid conflict between the objectives of different policies. They should also incorporate long-term action plans and tangible measurable targets and be implemented and monitored by independent apolitical bodies.

- **Institutional changes:** currently there is a lack of institutional flexibility when dealing with issues of sustainability. Many institutions; public and private, local and national, have fragmented, disconnected policies and do not optimally employ various mechanisms such as subsidies, supervision and monitoring) to resolve sustainability-related issues. Short-term planning approaches and inappropriate application of incentives are commonplace – these need to be stopped. Many institutions lack the knowledge and understanding of sustainability issues and are slow in responding to new information and values also information is rarely freely shared or disseminated. Special consideration needs to be given regarding the more problematic schemes – which due to these problems provide the best learning opportunities for other parties in the public and private sectors and therefore should be quantified and disseminated to inform scientific, data-led decision making. Most of these problems are the result of embedded institutional bureaucracy; therefore, institutions need to be more flexible, open and accessible. It will be key that power generation and supply utilities need to shift from being pure energy and supply entities to becoming service providers, which will generate new business opportunities. The change to decentralised energy gives a great opportunity to move to smaller power generators and supply utilities fitting the ESCo model either owned as community interest concerns or as municipal bodies. If by municipal bodies this is essentially a return to the time pre-world war 2 when the national grid did not exist, and local authorities ran decentralised standalone local micro grids.

- **Sustainability feedback research:** it is crucial to recognise how the preferences of institutions and individuals impact on the success and failure of energy policies and projects both large grid related and decentralised sized. The understanding and evaluation of these effects will allow the improvement and refinement of policy instruments. More use of cost-benefit analysis should also be encouraged that takes consideration of the market as well as non-market benefits and costs, with real operational data being utilised as it becomes more available from smart grid systems.

- **Distribution of economic incentives:** fees, subsidies and taxes should be gradually employed to change the economic price of activities that interfere with or impact upon energy efficiency and sustainability, such as with the use of fossil fuels, and of those that are attuned with them as in renewable low carbon generation technologies. While elimination of fossil fuel subsidies altogether is unlikely to happen quickly due to the adverse effect on the low paid sections of society and so make fuel poverty worse, the government needs to find ways of sending strong financial signals to customers and the market with regards the more rational use of energy. This should be targeted so as to stimulate increased competition from localised decentralised energy generation and supply in the electricity and heat production industry.

- **Social aspects of policy instruments:** present legislation fails to incorporate and address household/residential behaviour and its associated emissions. Therefore, policies should take into account the different consumption patterns based on the types of household, including income – this level of data should become more available with the uptake of smart metering into residential and commercial buildings. Policy should represent a mix of institutional support and penalties, despite the obvious political and social sensitivity of this. Conversely whilst the energy consumption of dwellings is relatively high in the UK, there are no regulations that require energy users to reduce their energy consumption or personal carbon footprint.

- **Social awareness and education:** media awareness regarding sustainability and climate change should be improved to avoid inaccuracy and inconsistency in reporting to improve public awareness and understanding. To be effective, this information would need to be tailored to the audience – general distribution should be avoided.

The majority of the drivers discussed in this paper have already an impact towards removing the barriers and addressing the proposed recommendations. Crucial drivers, such as belief in sustainability and willingness to act on it, play an important role in making the projects successful and can challenge most of the barriers when employed effectively.

Key recommendations would be:

- That Central Government needs to develop a long-term view to infrastructure investment rather than short term ineffectual “save then spend then save...” cycles, - to depoliticise Energy away from party politics. To move the strategy development and deployment outside the political process.
- For decentralised energy and Smart networks build on the BEIS HNDU work supporting local authority project profiles and develop local supply chain support programmes,
- Align skill uplift training packages in colleges and universities with supply chain diversification, - train and ready a workforce for businesses to utilise to drive growth,
- Pump prime flagship decentralised energy smart network projects with public finance packages to demonstrate investment de risking to financial institutions,
- Develop and undertake national and local communication programmes on the need for a new multi-faceted UK power generation mix from a few large plants for base load to local generation to balance out peak loads and ensure localised security of supply,
- Pursue financial incentives for private (business and public) local generation capacity which when linked with smart technology can contribute to national grid needs.

6 - Conclusion

The UK Government has acknowledged the potential for decentralised energy to contribute to meeting carbon emission reduction targets and provide localised energy security. It is clear that whilst technology is in varied states of deployment from off the shelf, mature and well understood to new innovative with little to-no-track record the real issue that can be viewed to holding back decentralised energy is the lack of a clear unified, integrated and focused direction from UK central government. Here we find the combination of the national and local trilemma's giving us the Energy Double Trilemma situation as shown here in Figure 56.

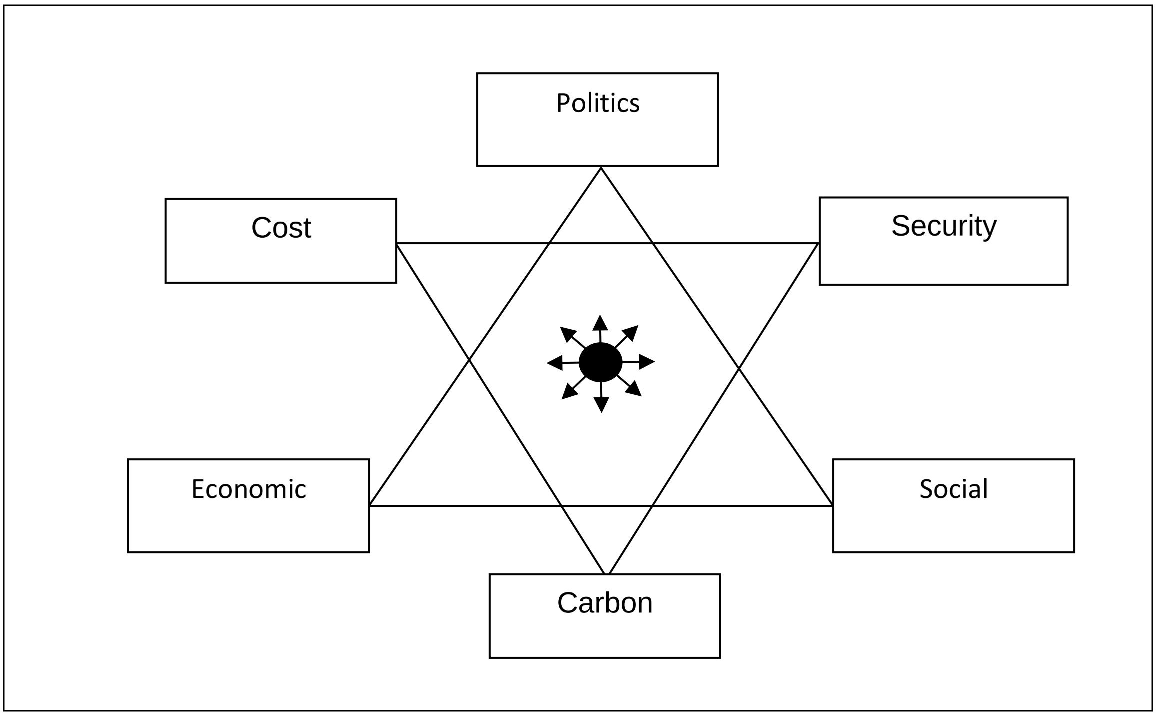


Figure 56: The Double Energy Trilemma

This Double Energy Trilemma results in a near impossible balancing act for national and local players looking to drive decentralised energy market growth.

There have been a range of financial incentives to drive low carbon energy take-up. Since 2000, discussions related to these incentives have either resulted in mixed signals regarding technology orientation, or short-term support has not been sustained long energy to allow supply chains to be established. There is a potential to implement a variety of decentralised energy projects in the UK, but many issues need to be addressed to realise the potential.

The design, implementation and operation of energy programme initiatives are often associated with the financial opportunities, but actuality it is also fundamentally linked to local governance issues and social concerns and motivations.

Technological challenges are mainly seen as challenges that just require research and development programmes which hence can ultimately be satisfactorily overcome, but they should also be allied to financial opportunities. Also, local authorities see planning concerns in the main linked to environmental issues; but they should also take into account the governance and financial aspects of their impact when they are in the design and planning submission aspect of the project.

This study investigated through observation the complexity and interconnectivity of the drivers related to decentralised energy, with governance drivers playing the most significant role, particularly in the form of regulation, whilst financial drivers – that are typically believed to be crucial – can be deemed to play a reduced role. As highlighted by the variety of drivers in the study, there are a variety of interconnected pathways to the increased development of decentralised energy in the UK.

Social, governance and financial barriers rather than technological barriers constitute the central problem areas for the increased adoption of decentralised energy, indicating multidimensional complexity associated with implementing and operating decentralised energy projects. Furthermore, the barriers cannot be simplistically divided into individual aspects.

Therefore, in order for these barriers to be addressed, there is an overwhelming need for developing an integrated approach that takes into account all aspects of project implementation – acting on it as a whole, as many barriers are interconnected and cannot be dealt without considering the wider context.

Currently in the UK it is viewed there is a lack of coherent policy that can handle with complexity and multiplicity of these interconnected barriers. A comprehensive and unified approach should therefore be developed, aimed at a certain collection of barriers rather than individual barriers – for example; the action of removing subsidies from conventional energy would likely just hurt the poorest and lead to higher levels of fuel poverty; distributing information regarding energy efficiency will be inadequate if associated energy efficiency measures are not available.

The drivers and barriers as experienced in the SSLEP Energy projects such as the Stoke-on-Trent DHN and the Keele University SEND are viewed as being similar to those anticipated by project developers for similar projects in the UK. There is potential, therefore, that the increased implementation of decentralised energy systems in the UK could also enhance social benefits and governance practice.

The case studies examined present a high potential for replication and scaling up in the UK. There is a need, however, for additional evidence and research examining the deployment of decentralised energy technologies to enable the characterisation of the complex interactions among the range of interrelated social drivers and enablers that influence implementation of decentralised energy in the UK.

Therefore, it is viewed from this study that focused research is needed in order to provide an in-depth understanding of the potential barriers and drivers for decentralised energy technologies and their potential contribution to the UK national carbon reduction targets.

This is an observational study, carried out by a resident LEP Board member, of the way the Stoke-on-Trent and Staffordshire LEP needed to develop, scope and guide its economic regeneration proposals into the Whitehall City Deal assessment system. The regeneration offer was centred around a unique unconventional energy resource in its remit that would allow it to kick start a decentralised energy project and develop a corresponding supply chain diversification creating jobs and increased GVA through the market placement in the UK being of a higher nature then existing SSLEP employment sectors.

The key issue observed was that the development of support mechanisms is crucial to drive supply chain development, and that many central government policies and programmes models were not suited at best or at worst in direct conflict to achieving Local needs.

The City Deal sell into Whitehall was further complicated by a misunderstanding and appreciation of local situations when developing policy and support strategies – for example Whitehall presumes that technology "best practise" must be being followed in industry, when due to lack of stability in investment cycles business is not in a best practise situation and running inefficiently.

This lack of understanding and appreciation is compounded that the SSLEP City Deal "sell" into the Whitehall departments would not be some much about the technology barriers that constrict or the positive advantages that deployment would give, but more about how the proposals fitted with current Whitehall political cycles.

Therefore, the key barrier to developing long term decentralised energy projects, supply chains and uplifting skill sets which would drive driving economic regeneration is not a technology issue or lack of private finance, but politics itself in the constriction of meeting short term political goals at a national level. This was proven that during the drawn-out City Deal negotiations the process was suddenly seen to speed up in the run into the 2015 election with a sign off achieved in the political window of election showcasing - "what had been achieved by London Government in the give– not what had been achieved in the delivery".

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Appendix 1 – UK HNDU DECC (now BEIS) Local Authority Funding Rounds

Heat Networks Delivery Unit (HNDU) - Round 1 to 6 Funding Levels by Local Authority

Successful local authorities	Round 1	Round 2	City Deal Projects	Round 3	Round 4	Round 5^	Round 6^
Allerdale Borough Council		£ 101,700					X
Barnsley Borough Council		£ 36,850					
Basingstoke and Deane Council							X
Bath & North East Somerset Council		£ 95,000			£ 20,100		
Birmingham City Council	£ 120,600				£ 139,360		X
Blaenau Gwent County Borough Council		£ 103,850					
Bolton Metropolitan Borough Council					£ 36,850		X
Bournemouth Borough Council					£ 81,494		
Bradford Metropolitan Council	£ 66,666						X
Bridgend County Borough Council		£ 26,800			£ 26,800	X	X
Brighton and Hove City Council	£ 130,650			£ 53,600		X	
Bristol City Council							X
Bromsgrove District Council					£ 40,000		
Buckinghamshire County Council					£ 30,150		
Bury Metropolitan Borough Council				£ 44,000			
Calderdale Council					£ 46,900		
Cardiff Council	£ 245,000						
Ceredigion County Council					£ 30,000		
Cherwell District Council	£ 83,080					X	
Cheshire East Borough Council	£ 198,000				£ 56,950	X	X
Cheshire West and Chester Council				£ 214,400			X
City & County of Swansea	£ 26,800				£ 50,250		
City of Westminster		£ 90,200			£ 67,500	X	

City of York Council		£ 90,450					
Colchester Borough Council				£ 10,050	£ 16,750	X	
Copeland Borough Council		£ 123,470					
Corby Borough Council							X
Cornwall Council		£ 13,330		£ 10,050	£ 30,150		
Coventry City Council					£ 30,150		X
Crawley Borough Council	£ 40,200				£ 26,800		X
Derbyshire County Council							X
Devon County Council		£ 184,250			£ 73,700	X	X
Doncaster Metropolitan Borough Council	£ 26,800						
Dudley Metropolitan Borough					£ 92,460		
Durham County Council				£ 77,050			
East Hampshire District Council					£ 70,350		X
East Riding of Yorkshire Council		£232,490					
Eastbourne Council				£ 44,890			X
Eastleigh Borough Council				£ 57,921			
Eden District Council					£ 60,300		X
Exeter City Council							X
Flintshire County Council					£ 30,150		
Forest Heath District Council					£ 22,445		
Gateshead Metropolitan Borough Council				£ 204,350			
Gloucestershire County Council					£ 50,250		
Halton Borough Council	£ 43,550						X
Hampshire County Council	£ 144,000						
Havant Borough Council							X
Herefordshire Council					£ 67,000		X
Hull City Council (City of Kingston upon Hull)		£63,972					X
Kent County Council					£ 50,250		
Kirklees Metropolitan Borough Council				£ 46,900			

Knowsley Metropolitan Borough Council		£44,220					X
Lancashire County Council				£ 26,800			
Leeds City Council				£ 62,310			
Leicester City Council							X
Leicestershire County Council					£ 88,600		
Lewes District Council				£ 63,400			
Lincolnshire County Council					£ 80,400		
Liverpool City Council	£ 10,500						
London Borough of Barking & Dagenham					£ 40,200		
London Borough of Camden		£64,480				X	
London Borough of Croydon						X	
London Borough of Ealing	£ 50,500						
London Borough of Hackney		£94,470					
London Borough of Haringey	£ 80,000				£ 77,050	X	X
London Borough of Harrow					£ 41,540		X
London Borough of Havering					£ 58,290		
London Borough of Islington	£ 55,067				£ 263,645	X	
London Borough of Lambeth				£ 110,282		x	
London Borough of Lewisham				£ 53,600		x	
London Borough of Merton	£ 20,000	£ 53,600					
London Borough of Redbridge					£ 80,400		
London Borough of Sutton	£ 101,342				£ 17,420		x
London Borough of Tower Hamlets							x
London Borough of Waltham Forest					£ 87,736		
Luton Borough Council							x
Manchester City Council	£ 30,000	£ 33,333			£ 68,600		
Middlesbrough Borough Council					£ 67,000		
Milton Keynes Council				£ 52,973			
Neath Port Talbot Council		£ 40,200					

Newcastle upon Tyne City Council		£ 94,250					
Newhaven Town Council					£ 28,140		
North Devon District Council					£ 20,000		
North East Lincolnshire Council							x
North Tyneside Council					£ 90,450		
North Warwickshire Borough Council				£ 28,716			
Norwich City Council					£ 20,100		
Nottingham City Council	£ 186,608						x
Oxford City Council	£ 16,667			£ 91,120			x
Plymouth City Council	£ 73,700				£ 144,050		
Poole Borough Council				£ 73,783			
Portsmouth City Council				£ 48,540	£ 45,784	x	
Reading Borough Council				£ 56,950			x
Redcar and Cleveland Borough Council			£ 136,397				
Royal Borough of Greenwich	£ 83,750					x	
Royal Borough of Kingston upon Thames	£ 40,200						
Rugby Borough Council					£ 32,830		
Runnymede Borough Council	£ 16,750				£ 34,944		x
Salford City Council	£ 30,000				£ 30,000		
Sandwell Metropolitan Borough Council				£ 63,650			
Sefton Metropolitan Borough Council		£ 26,800					
Selby District Council		£ 36,850					
Sheffield City Council		£ 30,150					
Slough Borough Council							
Solihull Metropolitan Borough Council					£ 50,000		x
South Gloucestershire District Council				£ 112,040		x	
South Oxfordshire Borough Council							x
South Staffordshire Council					£ 22,110		
South Tyneside Metropolitan Borough Council					£ 26,800		

Southampton City Council				£ 215,000			
Southend-on-Sea Council					£ 23,450		
St Edmundsbury Borough Council					£ 17,755		x
Staffordshire County Council		£ 107,200				x	
Stockton-On-Tees Borough Council			£ 158,933				
Stoke-on-Trent City Council		£ 224,450				x	
Stratford-on-Avon District Council					£ 30,150		
Sunderland City Council				£ 80,400	£ 33,500		
Swindon Borough Council				£ 120,600			
Tameside Metropolitan Borough Council				£ 40,200			
The Council of the Isles of Scilly							x
Trafford Borough Council					£ 15,000		
Wakefield City Metropolitan District Council		£ 36,850			£ 73,650		x
Warrington Borough Council		£ 80,400					
Warwick District Council				£ 30,000		x	
West Yorkshire Combined Authority						x	
Wiltshire Council		£ 53,600		£ 10,000	£ 26,666	x	x
Winchester City Council							x
Woking Borough Council				£ 108,429			
Wychavon District Council				£ 53,600			
Wycombe District Council	£ 34,000						
Total	**£1,954,430**	**£2,183,215**	**£ 295,330**	**£2,265,604**	**£2,983,369**	**£1,480,719**	**£ 2,828,245**
						TOTAL	**£ 13,990,912**

ContactFor further information, please contact the Heat Networks Delivery Unit on: hndu@decc.gsi.gov.uk
https://www.gov.uk/government/publications/heat-networks-funding-stream-application-and-guidance-pack

^DECC will look to publish individual Round 5 and Round 6 grant funding amounts at a future date.

Appendix 2 – Geotechnical Resource Opportunity Study: Stoke-on-Trent City Area

The Industrial Heritage of North Staffordshire is due to the combination of material resources of Coal, Clay and Iron Ore which lead to the development of these as intertwined and supporting industries which were operating until as substantial economic drivers for the area until the mid-1980's. The Ceramic industry today is still present but in much reduced capacity now employing some a max of 10,000 people today compared to some 80,000 at its height.

The Ceramic industry is going through resurgence today due to marketing and brand considerations with some production volumes coming back from other parts of the World to where they were relocated due to cost considerations only in the last 20 years. The Iron and Steel industry has now gone in North Staffordshire from its Victorian presence such as at Apedale to the large Iron and Steel works at Shelton Bar which employed 10,000 people at its height of which the main works closed in 1978 – with its continuous cast production rolling mill plant operating until 2000.

The Coal mining industry supported both these industries directly in the form of coke production for Iron and Steel making and also methane gas in the form of VAM, Ventilated Air Methane used in the Ceramics industry and also at the Michelin Tyre manufacturing factory. All the mines are now closed – just the Apedale mining museum today having limited access to the coal seams on the edge of the coalfield.

The North Staffordshire Coalfield when it was effectively closed down in the 1980's and 1990's was left in position of both worked out areas and totally untouched coal measures to all depths. The unworked areas can be considered for the in-situ gas reserves known Coal Bed Methane whilst the worked-out areas could offer the potential for Coal Mine-water Geothermal and CBM extraction and/or accessing geothermal energy for power generation.

The unworked potential has been evaluated at Keele University with an exploratory drill into the unworked Great Row coal seam. This has at this time has arrived at an issue with faulting in the seam leading to the CBM assessment to be put on hold. The borehole as drilled to some 300m depth and a 300m lateral is now up for consideration as a deep geothermal test borehole.

The Local Authority acting in a pre-LEP period supported a cross public / private / academic sector group known as the LCIDG – Low Carbon Industrial Development commissioned a range of studies in 2009-2011 which established a pre-feasibility knowledge base in regard to the potential for energy extraction from CBM and Minewater Geothermal.

The studies principally undertaken by LCIDG members and Keele University utilised Coal Authority GIS, Geographical Information System for the North Staffordshire coalfield linked with ex Mining engineer and mine surveyor knowledge to establish the potential in gas position.

Wardell Armstrong LLP has an extensive in-house knowledge base from ex regional coal mining surveyors of the local coalfield linked with the geo-technical research and academic skill set at Keele

University, a view of the CBM, CMM and Geothermal Energy potential was identified. Key to this was the interpretation of Coal Authority data for the worked regions of the coalfield.

The initial studies showed that whilst further technical work was required to fully quantify the potential, the opportunity for exploiting CBM, CMM and Geothermal Energy is present. If the resources are accessible this has the potential to place Stoke-on-Trent and Newcastle-under-Lyme urban areas in unique position to access and utilise a secure energy resource.

The focus is on the Central Northern areas of the coalfield as the South and South West areas are already licensed by Department of Energy and Climate Change (DECC) to others. However, there may be potential for accessing Geothermal Energy in the South and South West areas.

Areas for CBM potential are likely to be present in the deeper unworked seams of the coalfield. The shallower seams, due to them being in a fully or partially recovered (flooded) state may offer Geothermal Energy opportunities.

Data for the worked seams was obtained from the Coal Authority. This was examined in a Geographic Information System (GIS) to establish potential areas for CBM/CMM and Geothermal Energy extraction.

The areas of unworked coal possibly provide CBM resource and the worked areas are expected on the whole to be recovered (flooded) and therefore contain a potential Geothermal Energy resource.

This technical appraisal is developed on the basis that a baseline view on possible commercialisation models is developed. The respective parties (Local Authority (LA)/Local Enterprise Partnership (LEP)/North Staffordshire Chamber of Commerce and Industry (NSCCI)/Private Sector partnerships/NHS etc.) can either:

Scenario 1 - Promote the opportunity directly to conventional oil and gas developers possibly with a utility distribution company or

Scenario 2 - Set-up a SPV to take a shareholding with a utility / gas company.

Scenario 1 leaves the area open to a conventional supply situation where no competitive edge would be secured for business or the local community whilst in Scenario 2 the local business and community could obtain preferential tariffs and secure energy supply due to a stake holding in a Special Purpose Vehicle (SPV).

To follow Scenario 2, it would be required that Stoke-on-Trent City Council (SOTCC) and its partners prepare a Petroleum Extraction and Development Licence (PEDL) bid option. It is suggested that supporting lobbying into DECC and Central Government may assist in the process.

The CBM, CMM and Minewater Geothermal study identified the following items and areas in the context of the energy potential for the Unitary Authority Area of Stoke-on-Trent:

1. Identify the PEDL (Petroleum Exploration and Development License) position,

2. Identify the placement of the high-energy user ceramic businesses,
3. Identify surface pit head positions for active mines post 1945 for,

Apedale	Hanley Deep Pit	Park Hall
Berry Hill	Harriseahead	Parkhouse
Birchenwood	Hem Heath	Racecourse
Chatterley Whitfield	Holditch	Silverdale
Fenton	Kemball	Sneyd
Florence	Madeley	Stafford
Foxfield	Mossfield	Victoria
Glebe	Norton	Wolstanton

4. Identify the extent/boundary of underground workings for each pit head position.
5. Identify polygons of unworked coal areas over study area.
6. Indicate in supporting report aspects of underground mining activity such as:
   - Worked/un-worked seams;
   - Depth of seams – shallow / medium / deep (scaling in metres);
   - Likely state of worked seams – dry / flooded / flooding;
   - Workings interlink state at point of mine closures.
7. Quantify and map the insitu energy reserves,
8. Develop initial commercialisation models for consideration with the CIDG and then into the newly created Local Enterprise Partnership.

Establishment of PEDL Situation

The PEDL (Petroleum Exploration and Development License) situation in the study is shown on A2 Schematic 1 - the information is sourced from the PEDL DECC portal at: https://www.og.decc.gov.uk/information/index.htm as at end November 2010. The PEDL disposition in the Stoke-on-Trent area is shown below:

SSLEP – Stoke-on-Trent City Area PEDL position

The area's PEDL Prime License Holders being:

DECC PEDL Ref	Prime License Holder
PEDL197	CELTIQUE
PEDL141	EGDON
PEDL040 (Part)	NEXEN
PEDL040 (Part)	GREENPARK
PEDL056 (Part)	GREENPARK
PEDL056 (Part)	NEXEN
PEDL057	GREENPARK
PEDL078	WIMP
AL010	GREENPARK
PEDL196	GPL
PEDL198	GPL
PEDL115	ISLAND

As can be seen certain PEDL have shared license positions – in such circumstances the main PEDL areas is either subdivided and operated in a sub contract / sub license position or is operated fully in a shared stakeholder position. In plan ST11971-001 in Appendix 1 in addition to the GIS layer map a fully list of the positions is given for each PEDL, as on the DECC website (as at 17th December 2010).

As of the 14th Onshore PEDL (Petroleum Exploitation and Development License) round held by DECC/BEIS in 2014 (Bidding round open July 2014 until Oct 2014) Norcross Group Holdings Ltd (who own Johnson International Ceramic group) has applied and won the PEDL rights for a CBM well development for the OS area SJ84c covering the central area of Stoke-on-Trent consisting of Etruria Value where large areas and volumes of un-worked coal resource sit. In the central area of the valley in the area known locally as "Festival Park" due to the earlier post Shelton Bar Steelwork regeneration National Garden Festival project in the mid 1980's. Such National Festival Garden parks being a regional regeneration policy tool by the Thatcher Government to rejuvenate old heavy Industrial derelict land areas where developed in Liverpool 1984, Glasgow 1988, Gateshead 1990, Ebbw Vale in 1992 and in Stoke-on-Trent in 1986).

This SJ84c PEDL area in central Stoke-on-Trent is of interest as the 30 plus coal seams from the surface to around 1000 metres depth are largely un-worked unlike in the surrounding areas which are very heavily worked and now flooded. Being un-worked due to the now long-gone steelwork and gasworks infrastructures being on the surface to avoid the risk of local disruptive subsidence (it is not ideal to have a blast furnace suffering subsidence whilst operating) they have the potential for gas extraction from the coal seam complex at medium depth (c500m to 750m) and deep coal measures (c750m to 1000m). These coal measures are technically well reported in their worked panel areas either side of the valley where they are shallower as worked from the superpit complexes of Wolstanton, Chatterley Whitfield and Hanley Deep. All these mines closed down in the period through the 1970's into the late 1980's. From this recent mining activity, a detailed log of technical issues such as gas content, temperature was taken methodically every day. This data now supports the potential for accessing the un-worked coal areas for its inherent gas content. This is positive development as the coal bed methane gas would be well suited in its mix for use in the ceramic industry kiln equipment that sit in the locality – in fact this usage would essentially be a full turn of the circle as the Ceramic industry was using gas from the coal industry for most of the 20th Century with the kiln equipment designed for that gases combustion profile.

Accessing the gas using Coal Bed Methane technology has its problems though – the coal seam strata is well known to be subject to heavy faulting and whilst most major and many minor faults are geotechnically placed and understood there will be many unknown minor faults in the un-worked volumes which could cause considerable problems if drilled.

This level of problem is supported by the recent experience at Keele University where there was an exploratory CBM drill undertaken by the as then PEDL license owner Igas into the Great Row coal seam which is un-worked and at a shallow depth under the University. The Great Row seam is a 3M thick seam at c300M depth under Keele and relatively gas rich – at this depth mining records indicate it to have a gas content of c5M3 / 1 Tonne – this seam is runs under the city to a greater depth in the Etruria Valley are to some 800M depth at which due to compressibility pressure the gassing content was measured and recorded by the NCB as being +7.5M3/Tonne. But on drilling at Keele the seam was found to be well faulted with the drill head continually finding itself "outside" the seam run which was well dislocated. IT appears that even though directional drilling technology has made large strides in its ability to pinpoint the drill head position over the last 20-30 years mainly due to North Sea oil exploration at Keele with the sensing/ sample unit some 25M back from the drill head it was found that the drill head was continually hunting its way in and out of the Great Row coal seam due to these small but intrusive dislocations. Therefore, at Keele the potential for accessing coal seam gas has been put on hold until drilling technology advances. There are now project development plans to consider the borehole from this CBM trial for other purposes such as a deep Geothermal test facility.

Thus, from this Keele University experience there is a degree of concern that a drill into the Great Row and / or adjoining seams in the deeper Etruria Valley system could encounter the same level of dislocation issue. This is where the present level of geotechnical view splits into a number of differing camps – some believe that the same level of seam dislocation will be present at all depths whilst others believe that it will be less due to it being deeper and therefore less prone to near surface disturbance. The PEDL owner to attempt to understand the seam structure is in discussions with Stoke-on-Trent City Council and its potential Deep Geothermal drilling partner to access the core samples that could be drawn if a Deep Geothermal drill is undertaken.

It is clear that a wider opportunity is available here in terms of supply chain development related to drilling in the wider sense noting that it is accepted that drilling for CBM or Deep Geothermal assets utilises some 90% of the same drilling hardware and has a common thread in the professional Geotechnical skill base required – this professional and academic skill base is established at Keele University and is planned to grow with the recent academic team expansion with world renowned geotechnical appointments. The hardware supply chain base is a clear growth area in terms of regeneration opportunity for the area – it should be noted that Shale Gas development requires essentially the same skill base and hardware dimension also. Coal Bed Methane is a area specific opportunity in the UK with an emphasis on coal assets that lie in the coalfields that have been worked for many hundreds of years – these also are often associated with Urban on surface settings which have a level of infrastructure to link into – for Shale Gas the situation tends to be different with many field in rural settings thus raising the environmental and public resistance to its development.

Identify ceramic businesses placement as energy demand nodes

Regional Ceramic manufacturers in the CBM opportunity study were identified and their plant address point information (post codes) obtained from public sources (Thomson's directory / Yellowpages / websites etc); these address points, for the Stoke-on-Trent area, were placed into a GIS layer. The plant position is shown combined with the PEDL to show who is in and who is not in a PEDL Licensed area as per the 14th PEDL onshore round.

The Ceramic plants detailed for the area being as follows:

Table 1: Regional Ceramic Plant Locations

Company	Post code	PEDL Area
Aynsley China Ltd	ST3 1HS	**AL010**
Bridgewater Pottery Ltd	ST1 3EJ	**Vacant**
Caradon Bathrooms Ltd	ST7 2DF	**Vacant**
Churchill China (UK) Ltd	ST6 5NZ	**Vacant**
Crown Trent China Ltd	ST3 2TE	**AL010**
Duchess China	ST3 1PB	**AL010**
Dudson Duraline Ltd	ST6 2AR	**Vacant**
Dudson Duraline Ltd	ST6 4HF	**Vacant**
Dyson Group	ST4 6EP	**Vacant**
H & E Smith Ltd	ST1 2LR	**Vacant**
Hudsons Fine Bone China Ltd	ST3 1PP	**AL010**
Ibstock Brick Ltd	ST5 6BH	**PEDL56**
Ibstock Brick Ltd	ST5 7RB	**Vacant**
James Kent (Ceramic Materials) Ltd	ST4 2HB	**PEDL57**

Jesse Shirley & Son Ltd	ST4 7AF	**Vacant**
Johnson Matthey	ST7 3AA	**Vacant**
Johnson Tiles Ltd	ST6 5JZ	**Vacant**
Josiah Wedgwood & Sons	ST3 1LG	**AL010**
Josiah Wedgwood & Sons	ST12 9ES	**AL010**
Portmeirion Potteries Ltd	ST4 7QQ	**PEDL57**
Ross Ceramics Ltd	ST4 8HX	**PEDL57**
Roy Kirkham & Co Ltd	ST6 5DB	**Vacant**
Royal Stafford Tableware Ltd	ST6 4EE	**Vacant**
Steelite Int. plc	ST6 3RD	**Vacant**
Taylor Tunnicliff Ltd	ST3 1PH	**AL010**
W. Moorcroft plc	ST6 2DQ	**Vacant**
Wade Ceramics Ltd	ST1 5GR	**Vacant**

With the 14th PEDL round now awarded and the SJ84c won by Norcross it is viewed that all the "vacant" sited companies will now fall into the licensed CBM PEDL position.

Note: this list is not exhaustive as there are a number of ceramic companies in the city area who are not listed or who do not have websites, but it is believed this listing represents +80% of the thermal energy consumption of the Ceramic Industrial sector. Also, the public domain information is of varying ages and it is possible plants may have been relocated/ moved in 2010.

Surface pit head positions

The pit head positions for the following were cross matched with the Coal Authority datasets and showed the following by mine name, as being active in 1962, See table 2 below:

Table 2: Pit head positions (as at 1962)	
Apedale	Norton
Berryhill	Park Hall
Chatterley Whitfield	Parkhouse
Fenton	Silverdale
Florence	Sneyd
Deep Pit	Stafford

Hem Heath	Victoria
Holditch	Wolstanton
Mossfield	

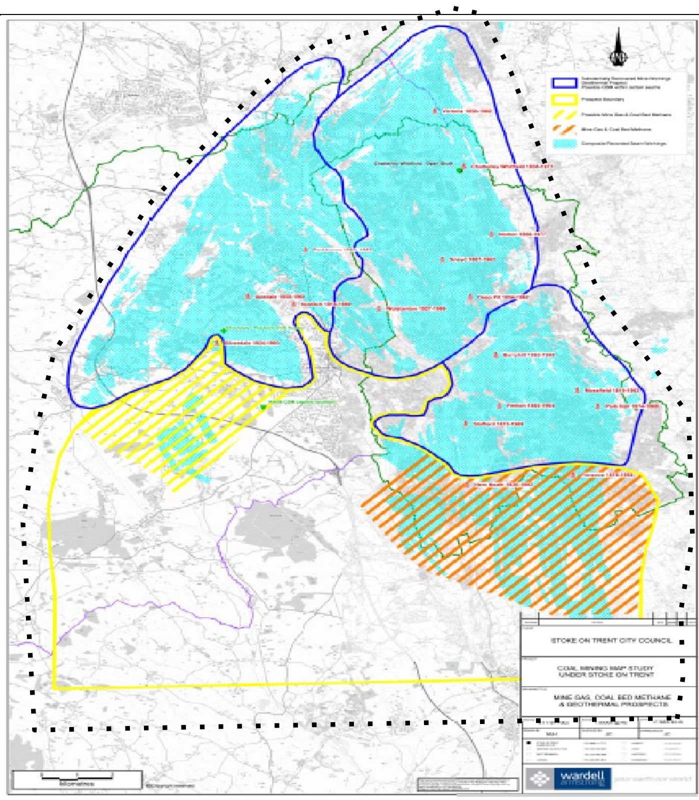
Item 4: Show extent/boundary of underground workings for each pit head position

The North Staffordshire Coalfield is for simplicity, described as one end of a "bathtub" with the coal seams being at or near the surface at the West, East and North aspects, whilst being at its deepest in the central area and to the Southern end (plunging syncline).

The underground workings from a number of collieries within the North Staffordshire Coalfield were joined by purpose made connections (roadways) and inadequate barriers. Accordingly, a view of the individual colliery working areas does not add to the study. For example, it is known that Wolstanton colliery was purposely connected to Chatterley Whitfield, Sneyd and Deep Pit collieries.

In preference, a composite plan was constructed from the 76 layer dataset from the Coal Authority to show the overall extent of recorded mine working in all seams and at all depths. This area was then subdivided into discrete 'ponds' within which the various horizons of mine workings are believed to be connected whilst the ponds themselves are not believed to be interconnected. In total this identified five potential 'ponds' within four areas.

A2 Schematic 2: - Extent of North Staffordshire Coal Field



Boundary of North Staffordshire Coalfield shown by - . . . .

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It should be recognised that the identification of the ponds defines precision and is based on a general view formed from mine plans, past researches and knowledge of incomplete records. Where the coal seams are close to the surface (on the western and eastern limbs of the syncline) it is likely that unrecorded workings will be present (pre-dating records) and in these areas smaller and unconnected ponds will have formed and be likely to have recovered.

The composite plan highlights large regions across the city of complete columns of unworked coal seams at all depths – shown by the white areas.

Coal Authority GIS polygons of unworked coal areas over study area supporting report aspects of underground mining activity

The 76-layer Coal Authority datasets include a number of duplicated seams and seams that have only been worked in isolated locations. Of the 76 layers, it is considered that there are some 40 workable seams within the North Staffordshire Coalfield. This probably represents the highest number of viable seams in any coalfield and in this regard, makes the North Staffordshire Coalfield unique.

This Coal Authority data identifies four main areas across the coalfield:

Area 1

This area is in the South of the coalfield where PEDLs have been registered and incorporates the Hem Heath/Florence pond and the Silverdale New Mine pond.

Shown with a yellow border this area encompasses an area of worked coal related to the Hem Heath / Florence pit complex in the East and also a small worked area related to the Silverdale New Mine in the West; the majority of the area represents un worked coal reserves at all depths. It is believed that this area holds good prospects for CBM evaluation –for the future.

It should be noted that two commercial extraction points related to CMM are also operating one at Trentham Lakes related to the closed Hem Heath pit head, the second is placed near to the closed Florence pit head. Both these are accessing gas arising from worked coal seams. It is understood that mine water has not fully recovered in this area and it is suggested that it could take until 2020 to 2030 until it does.

The Hem Heath/Florence complex was physically isolated from the worked areas to the North by purpose installed dams to prevent ingress. Prior to abandonment of the Hem Heath/Florence complex it was reported that water inflow into the mine was minimal. . Due to this it is viewed as being predominantly dry, and therefore will have good CMM potential in worked seams and have a good CBM potential in the un-worked deeper seams such as in the Banbury/Cockshead/Bullhurst seams. There are also large areas providing the potential for CBM where seams have only been partially worked. Coal resources and workings in this area are at depth, generally greater than 400m.

The status of recovery of the Silverdale New Mine is not known and needs further investigation. The old mine was pumped to prevent minewater ingress into the New Mine which takes the form of an island adjacent to the M6 Keele Services Areas. It is not known whether the pumping has been halted and/or whether the New Mine is recovered/recovering. At this stage, it has been assured that the mine workings in this area have not recovered in which case this part of the mine could provide for CMM, conversely if recovery has occurred then the long access drifts could provide for a Geothermal Energy source.

There are no workings recorded beneath the Hartshill hospital complexes, Penkhull and the Westlands areas. This area is viewed as having potential for CBM evaluation.

Area 2

This area is in the North-West part of the coalfield and relates to the Silverdale Old Mine / Holditch ponds. Whilst these mines were never purposely connected, there are possible connections in the outcrop areas and the mine water is expected to have fully recovered in this area.

The PEDL for this area is taken in its Southern portion, the Northern portion is not presently in a PEDL a large proportion of this areas has been mined.

Due to the recovery state (flooded) the opportunity for CMM is believed to be limited. CBM potential exists in the deeper unworked seams. Within workings in this areas extending down to 1,000m, this provides the potential for Geothermal Energy but the intensity of overlying workings could provide a constraint.

Area 3

This area is in the North-East part of the coalfield and relates to the Wolstanton/Chatterley Whitfield pond, this is viewed to be partially to fully recovered/flooded in the worked areas.

This area includes sections that underlay the town centres of Newcastle (North), Tunstall and Burslem.

Further east in this area the situation becomes more complex. It is known that in the extreme North East of the area (or pond) that mine water at the Chatterley Whitfield pit has recovered. This is evidenced from the Hesketh shaft which is flooded to within 6-8 metres of the surface. The expectation on closure of Wolstanton Colliery (the last active mine in this locality) was that the mine water would recover completely within a few years of pumping ceasing, this would result in water rising both at Chatterley Whitfield (as is being seen) and also within the Wolstanton mine areas which is considered to be the natural “sump” of the pond. The minewater recovery level within this part of the Wolstanton mine is unclear. The former Wolstanton shafts (at one time the deepest in the Country) have been infilled and the ASDA store now occupies the former pit head site. The worked seams provide the potential for Geothermal Energy particularly as this pond incorporates some of the deepest workings in the Country (Cockshead at c1,100m depth beneath Tunstall). This can be partially assessed by undertaking a temperature gradient study in the Hesketh shaft which provides a unique facility with an open shaft to some 500m depth.

The potential for CBM lies in unworked areas of coal in a number of seams including the Great Row. Note this is the seam accessed by the Keele University borehole which is currently undergoing evaluation. Unworked deeper seams such as the Ten Feet, Banbury, Cocksead and Bullhurst have large areas unworked at -1100mOD and deeper lying principally on a North South axis under the City. It is considered that these seams may provide CBM potential. To understand the potential a view on the permeability (ability to release gas of these seams) could be gained from coalfield gas records.

It is understood that the central portion of these seams were not worked during the 1980s and early 1990s due to increasing depths and sensitive surface structures. This means that under the city area there are numerous deep and relatively thick seams which are unworked and not subject to a current PEDL.

Identification of access windows to CBM areas

To assist in the visualisation of the intensity of worked areas plans a below surface GIS model was developed. Used in conjunction with Coal Authority GIS data a series of individual seam layers' models have been produced which assist in an understanding of underground mining activity. They have been selected across the depth range of the coalfield and also because they represent seams with a range of thickness being 0.8 metres and above, the seams are listed below in Table 3:

Table 3: List of Seams of Interest (due to seam thickness)

Image Ref	Seam CA Code	Seam Name	Depth/Metres below OD at Hem Heath	Thickness/Metres (range spread)
1	AG020A	Peacock	235	0.8 (0.5-1.5)
2	AH020A	Spencroft	252	0.8 (0.3-2.6)
3	AI020A	Great Row	283	1.8 (3.4)
4	AJ020A	Cannel Row	300	1.5 (2.8)
5	BA020A	Winghay	424	2.0
6	BA022A	Bigmine	454	2.0
7	DA020A	Rowhurst	553	1.5 (1.7)
8	EB020A	Moss	735	1.7
9	FC240A	Yard / Ragman	795	3.2 (0.2-2.7)

10	FC020A	Hams	816	1.5 (0.3-1.5)
11	FE020A	Ten Feet	902	1.8 (3.5)
12	FF040A	Bowling Alley	934	1.4 (1.2-1.5)
13	FF020A	Holly Lane	955	1.2 (1.1-1.3)
14	FG020A	Hard Mine	975	1.2 (1.0-1.5)
15	FH020A	New Moss	993	1.1
16	GB020A	Banbury	1087	1.8 (1.3-2.3)
17	GC020A	Cockshead	1120	2.4 (2.3-2.6)
18	GF020A	Bullhurst	1161	3.4 (1.3-5.5)

The Great Row worked areas are seen to be in isolation, they sit in the middle of the coalfield area. From Table 3 above it can be seen to sit in the top third of the seam depth range. It is believed that the Great Row will have areas for consideration for CBM in the unworked areas and Geothermal Energy in the worked areas.

The Banbury worked areas are seen to be in isolation, they sit in the Western and Eastern limbs of the coalfield area and show a worked depth range from +120mOD in the West/+180mOD in the East to -1,000mOD in the centre (under the Festival Retail and Business Park area), the Banbury as can be seen from Table 3 above, is in the bottom third of the seam depth range. Due to the extreme depth the worked areas stopped around the -1,000mOD point but the seam is known to continue at an incline to greater depth in a complete state from Wolstanton to West of Newcastle to the worked areas West of Crackley and Silverdale.

This offers a very large area of unworked coal which could be considered for CBM evaluation in the Eastern portion as this sits in an unlicensed area. It is expected that as the seam is unworked it will be in a semi-dry state.

The eastern part of the coalfield and includes the Stafford/Fenton pond. This pond is regarded to be substantially recovered.

The workings in this area extend from shallow outcrop workings in the east to deep resources of coal in the west (>1,000m at Trent Vale). Whilst a number of seams have been worked there are significant areas with each of those seams which have not been worked.

The mining and recovery status of this area provides little prospect for CMM but could be a source for CBM and Mine water heat.

Liaise and work with Keele University in regard to geo-technical input for CH_4 and geothermal energy assessment

CBM development

The following is viewed as a basis for a utilisation model. This is based on Keele University's experience working with Nexen and their evaluation of the potential from the Keele based borehole into the unworked Great Row seam underlying the University site.

For Evaluation:

- Single evaluation borehole (to required depth related to seam);
- Sump for water drain off to greater depth;
- Lateral drill for ~300m (maybe extended later);
- Surface gas monitoring station.

For Exploitation:

- Radius of draw viewed as 300m;
- Drill additional laterals and star off radial laterals along the primary laterals;
- Surface pipework / compressor / cleaning stations;
- On site use in generator set (gas engine / micro turbine);
- Inject into national or local gas grid for third party use.

The baseline cost for a CBM project as above is c£2.5-4million, for Keele this is viewed as if viable as supplying virtually 100% of its thermal power needs for 20-25yrs – based on a today gas usage of c10 million m3 pa. Models for CBM exploitation are discussed in following sections 4.8 and 4.9.

CMM development

Coal Mine Methane development is already being undertaken in PEDL'ed areas operating under mine drainage licenses around the city at:

- Green Gas Power Ltd are believed to be draining methane from the abandoned Silverdale New Mine and selling it to local users via the North Staffs Gas Grid (a privately-owned pipeline) and the National Gas Grid after a gas clean-up process;
- Alkane Energy site near to old Florence site accessing worked areas to the South of the pit site;
- Greenpark site near to the Stoke City football ground on Trentham Lakes utilising the former Hem Heath site gas access to workings to generate exportable power to the national electricity grid. This is an example of a continuation of utilising the mine methane resource as when it was operating Hem Heath fed large proportion after self use on the mine site to the nearby Michelin factory where it was the prime fuel in the tyre factory boiler house. There it was used to raise steam which is a key part of the tyre making process in steam and hot water curing. When the mine closed the Michelin continued to take the gas from the mine shaft system – but in around 1998 a proposal was taken up to give a more secure long term steam supply as it the mine methane would eventually run down. This was originally offered by a Scottish Power solution to site a Natural Gas powered 50MW gas turbine package. This was built and supplied 10% of its power and all

of its steam via a heat exchanger system to the Michelin site, the power station and has since moved into EoN ownership.

The CMM evolution and take off continued and was calculated by mining engineers to be sustainable as a fuel source until c2020 when it was viewed that the progressive mine flooding as no pumping is running would start to fill the main vertical shaft system and hydrostatically seal of the still present Mine Methane resource. As the period 2020-2030 is now relatively near it is expected that the Alkane spark ignition engine station on Trentham Lakes will be closed down. To maximise the revenue generation the engine sets are run at peak demand on the National Grid in the morning in the evening periods.

CMM is therefore already established in PEDL'ed areas around the city, further analysis is required to detail and quantify the extent of recovery due to recovering minewater in the two Northern pond areas (as shown in ST11971-002). This will indicate where there is potential for Geothermal Energy using the mine water or where it is dry where CMM potential exists.

Mine water heat development

Mine water heat development is interlinked with CMM development – further analysis and study is required to quantify the recovered / flooded state in the Northern ponds, two potential test areas exist via temperature gradient testing at either:

- Chatterley Whitfield Hesketh shaft;
- Silverdale incline drifts.

There are large areas within the coalfield for possible mine water heat extraction is due to the depth of recovered mine water within mine workings. These could be expensive to access due to depth and intensity of past workings. Limited flows and reservoirs could also be a constraint.

PEDL Overview

There are 2 types of license in question the Petroleum Exploration and Development Licence (PEDL) is the name of the licence required to gain exclusive rights to explore for and produce petroleum in one or more specified blocks. The other type of licence in question is the methane drainage licences (MDL) which grants permission to get natural gas in the course of operations for making and keeping safe mines whether or not disused. The MDL grants no exclusive rights, so it can overlap geographically with one or more PEDL's. They generally cover much smaller areas than PEDL's, typically covering a single mine, although the Coal Authority holds a licence that covers the whole country. There is no requirement to be in ownership of a MDL to extract methane from coal mines or seams, only for mine operators in securing the safety of mines and the workings. But there is a requirement for ownership of a PEDL and permission of the Coal Authority to access the coal or disused mine for the extraction of methane for energy potential.

The award of a PEDL does not waive the requirement for the licensee to obtain access rights from landowners and PEDL's do not give exemption from other legal/regulatory requirements, oil and gas exploration and development activities are also subject to statutory planning, environmental and other permitting regimes. Persons wishing to enter coal measures or coal mines to conduct exploration for oil and gas also need agreement from the Coal Authority, which can make the need for a MDL redundant. Under the terms of a PEDL, licensees may not conduct activities such as the drilling of wells, installation of facilities or production of hydrocarbons without the authorisation of the Secretary of State and licensees are required to provide proof to the DECC that the relevant planning and other permissions and consents have been obtained.

PEDL's are valid for a sequence of periods, called "Terms" which are designed to follow the typical lifecycle of a field: exploration, appraisal, and production. Each License expires automatically at the end of each Term, unless the Licensee has made enough progress to earn the chance to move into the next Term. The exploration phase lasts for 6 years and if the agreed work programme is completed the project can then move on to the appraisal and development phase. This phase lasts for 5 years and move on to the production phase if the Secretary of State has approved a development plan. The final production phase has an initial term of 20 years but the Secretary of State has discretion to extend past this if production is predicted to continue.

PEDL Application Process

The Department of Energy and Climate Change, DECC, wishes to maximise the exploration for petroleum resources, so they are keen to allow all sizes of companies with a mix of large multinational to small niche. Even so there are still some specific requirements of all sizes of licensee; this is so they no potential opportunities are blocked by companies with insufficient funds or expertise. All new entrants who wish to join or acquire a licence have to supply a range of information; first of all, they have to establish the financial capabilities of the applicant. Financial capacity becomes especially relevant where there is a clear programme of new work that needs to be funded, such as exploration drilling. In some cases, the work may constitute a commitment to the Secretary of State (e.g. an Initial Term Work Programme, or work designed to end a licence's fallow status). But overall the applicant must demonstrate that the finances are there to complete the work proposed in the initial application. After this there is a large amount of emphasis placed on the applicant's ability to pay decommissioning costs, it is expected that the company provides reasonable and realistic estimates of those costs, including contingencies (for example, including the cost of counter drilling when drilling a well). Where an estimate looks unrealistically low, there may be a need to see evidence that it can be achieved (for example, a signed agreement with a drilling company). Generally, DECC wants to see that the company will be in a financially strong position for the duration of the licence, if the company does not already have a big net worth already (e.g. big oil company) they will need to see that the funding is already in place to complete the proposed work. Another requirement is that there is enough technical expertise in place to be able to complete the proposed project in the licence application.

Date of PEDL Application for 14th Onshore Licensing Round

The 14th onshore licensing round ran in 2014 following a 3 year period of delays, the exact date was subject to the outcome of the ‘Strategic Environmental Assessment (SEA)’. This was released in July 2010 for comment, with a deadline for comments being the 10th of November 2010, then there were subsequent delays in following a wait for the outcome of geotechnical studies carried out around the shale gas test drilling being carried out by Cuadrilla in Lancashire. Following the outcome of the SEA and the Lancashire study DECC was in a position to request the translation and publication of a Notice for the Official Journal of European Union detailing the announcement of the UK's 14th onshore Oil and Gas Licensing Round, which normally takes around 6-8 weeks. After this a 90-day application period starts.

Application Process for a PEDL

Once the 90-day application period has been opened an application will then need to be completed, detailing all of the parties involved and the suitability to become a licensee. When the 90-day application period is opened, the exact PEDL locations will be released and the exact criteria used to assess applications such as the following criteria used to assess applications:

- (*a) The financial viability of the applicant and its financial capacity to carry out the activities that would be permitted under the licence during the initial term including the work programme submitted for evaluating the full potential of the area within the block or blocks applied for;*
- *(b) The technical capability of the applicant to carry out activities that would be permitted under the licence during the initial term including the identification of hydrocarbon prospects within the block or blocks applied for. The technical capability will be assessed in part upon the quality of analysis related to the block or blocks applied for;*
- *(c) The way in which the applicant proposes to carry out the activities that would be permitted under the licence including the quality of the work programme submitted for evaluating the full potential of the area applied for;*
  (d) Where the applicant holds, or has held a licence granted under or treated as having been granted under the Petroleum Act 1998, any lack of efficiency and responsibility displayed by the applicant in operations under that licence.

14th PEDL Round Application approvals