Sheffield City Council

Investment Potential of Renewable Energy Technologies in Sheffield

Final Report

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Executive Summary

Arup was commissioned by Sheffield City Council (SCC) to review and update previous estimates of the investment potential of renewable and low carbon technologies in the Sheffield City area. This included an assessment of the key constraints and investment drivers as well as key economic and social development drivers for each technology.

The study is a key strategic building block to assist in SCC's ambitions to be an environmentally responsible city, based strongly on a policy of decentralised/low carbon energy. This work aims to effectively demonstrate to internal and external partners that the city is open for business by proactively highlighting key opportunities for development and investment.

Local case studies have been used to illustrate the diversity of projects available in Sheffield, to highlight some of the constraints and challenges as well as the benefits of investment in renewable and low carbon energy developments.

Estimated resource potential

The existing renewable energy capacity in Sheffield and deployment scenarios to 2020 and 2030 are summarised in Figure 1. The 2020 deployment scenario indicates that SCC's 100GWh annual generation target is achievable. The total annual generation from all technologies is estimated at 113GWh per annum by 2020.

The total estimated total long term resource potential for renewable energy generation in Sheffield is nearly 10 times the 2030 deployment scenario. This assumes that all of the available resource was economically and practically viable to develop. Deployment rates of micro-generation will be the most significant constraint to continued growth beyond 2030.

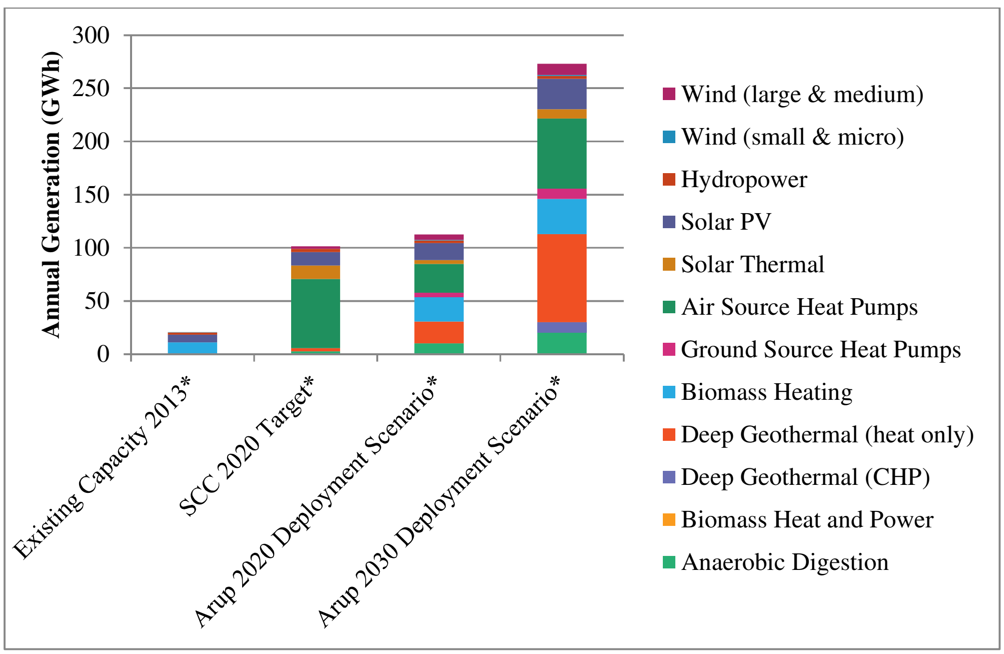

Figure 1 Total Estimated Resource Potential to 2020 and 2030

Micro-generation schemes

With ongoing central government support from the Feed in Tariff and Renewable Heat Incentive schemes, micro-generation will make a significant contribution towards achieving SCC's target of 100GWh of annual generation by 2020. Micro-generation schemes are expected to represent over 85% of the installed capacity and over 65% of the annual generation in Sheffield by 2020.

Micro-generation schemes will make up the vast majority of the 6,750 sites as shown in Figure 2. Roughly half are expected to be solar PV installations with the other half being made up of a combination of renewable heat installations.

Given the number of installations required, SCC should consider how to further support and encourage householders and businesses to invest in micro-generation. SCC should lead by example by installing micro-generation on council owned properties wherever technically and commercially viable.

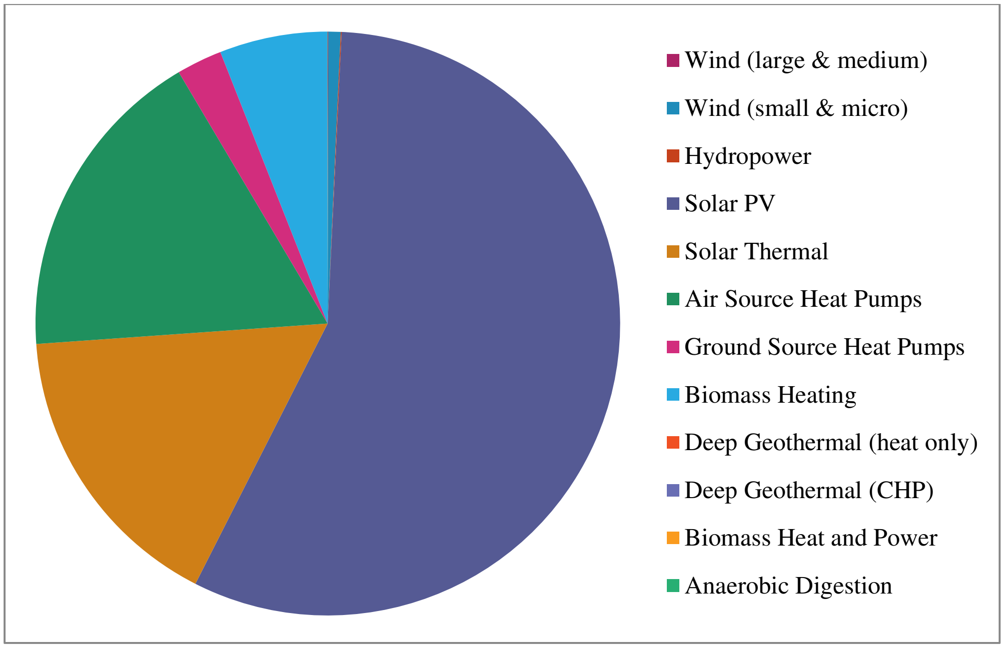

Figure 2 Numbers of installations per technology by 2020

Commercial and industrial scale developments

There are a number of potential opportunities for development of medium and large scale commercial renewable energy developments in Sheffield. The most significant opportunities are from wind energy, deep geothermal and anaerobic digestion. Developments will need to be sensitively sited to take into account key constraints including residential areas, green belt and the Peak District National Park. A number of potential sites are identified in Appendix A.

SCC should consider how to further support and encourage investment in specific technologies. A more detailed study to identify key sites which could be promoted for renewable energy development would be beneficial.

1 Introduction

Arup was commissioned by Sheffield City Council (SCC) in November 2013 to review and update previous estimates of the investment potential of renewable and low carbon technologies in the Sheffield City area. This includes an assessment of the key constraints and investment drivers as well as key economic and social development drivers for each technology.

The study is a key strategic building block to assist in SCC's ambitions to be an environmentally responsible city, based strongly on a policy of decentralised/low carbon energy. This work aims to effectively demonstrate to internal and external partners that the city is open for business by proactively highlighting key opportunities for development and investment.

1.1 Scope

This report builds on previous work produced by IT Power for SCC in 2006: 'Renewable Energy Scoping and Feasibility Study for Sheffield'. This has been compared with the preferred 'Renewable and Low Carbon Energy Capacity Methodology for the English Regions' produced by SQW Energy and Land Use Consultants for Department of Energy and Climate Change (DECC) and the Department of Communities and Local Government (DCLG) in 2010 (DECC, 2010).

Three local case studies have been used to illustrate the diversity of projects available in Sheffield, to highlight some of the constraints and challenges as well as the benefits of investment in renewable and low carbon energy developments.

Following on from this report, Arup will produce an investment prospectus with SCC to help publicise that Sheffield is open for business to attract inward investment in renewable and low carbon energy developments.

1.2 Report structure

This report is structured as follows:

Chapter 2 outlines some of the previous studies undertaken to understand resource potential in Sheffield and the recent targets adopted by SCC.

Chapters 3, 4 and 5 examine the available technologies for electricity generation, heat generation and co-generation respectively.

Chapter 6 provides a comparison of all of the technologies and the relative investment potential, taking into account both investor and SCC drivers.

Chapters 7 and 8 look at some of the delivery mechanisms available which are illustrated by four case studies.

Chapter 9 draws conclusions about the remaining renewable energy resource potential in Sheffield and makes recommendations for further work needed.

2 Previous Studies

There have been several previous studies and reports relating the available resource in Sheffield. These are summarised below in chronological order.

2.1 IT Power

In 2006, SCC commissioned a report by IT Power (IT Power, 2006) to help understand the potential for renewables in the Sheffield City area. Since then, there has been further national guidance on the methodology and assumptions to be used for estimating available resource and some key changes to the constraints in Sheffield. Furthermore, the introduction of Feed in Tariffs (FiTs) and the Renewable Heat Incentive (RHI) have radically altered the market for small scale renewables.

The report presented three scenarios for estimated renewables development to 2021:

- Low: 60 MW installed capacity, 86 GWh annual generation
- Medium: 84 MW installed capacity, 160 GWh annual generation
- High: 124 MW installed capacity, 243 GWh annual generation

2.2 DECC Methodology

In 2010, DECC and DCLG commissioned a study by SQW Energy and Land Use Consultants to identify a methodology for assessing resource potential in English regions (DECC, 2010). This methodology was intended to ensure that work in the regions is sufficient to deliver a step change in renewable energy deployment across the country, and to reduce the inconsistencies between regional assessments.

The methodology outlines a sequential process whereby constraints are applied progressively to reduce the natural resource as shown in Figure 3 below. However, the specific guidance in the DECC methodology is limited to developing an understanding of the practically achievable resource (stages 1-4) only.

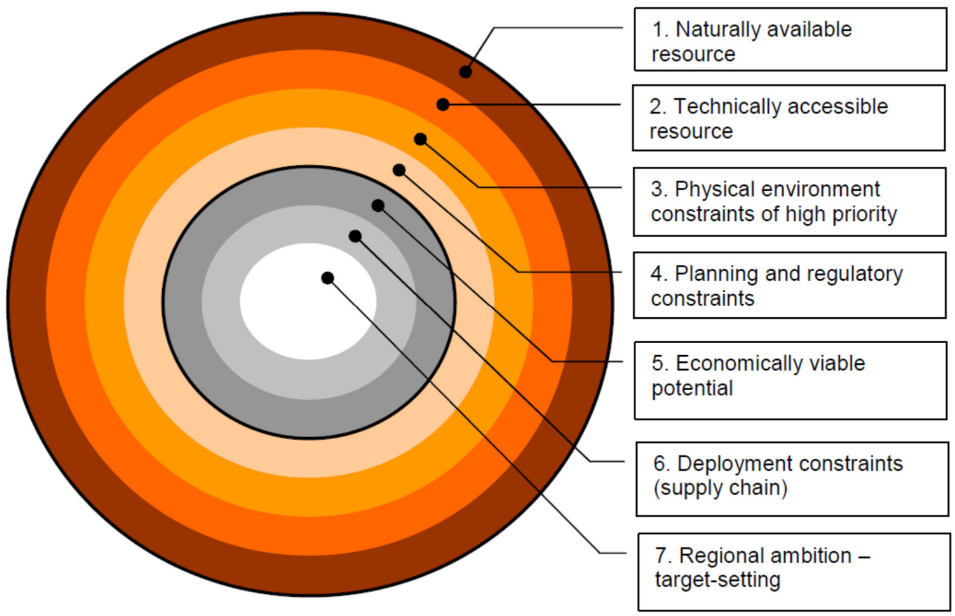

Figure 3 Stages for developing a comprehensive evidence base for renewable energy potential (Source: DECC, 2010).

2.3 Yorkshire and Humber Region

The DECC methodology was applied to the Yorkshire and Humber region in 2011 (AECOM, 2011). This study was commissioned by Local Government Yorkshire and Humber (LGYH) to assess the resource across the Yorkshire and Humber region. The study was intended to provide an evidence base to assist sub-regional stakeholders and local authorities in the preparation of their own targets, policies and strategies for renewable energy development at the sub-regional and local levels.

AECOM built on the DECC methodology to include assessments of:

- The total current[1] installed capacity in 2011.
- The practically achievable resource (stages 1-4) – some additional assumptions were made by AECOM to fill gaps left in the DECC methodology.
- The economically viable resource (stages 5-6) – this required a bespoke approach to be developed, based on AECOM's experience of advising on renewable energy projects combined with consultation with local stakeholders.

The report estimated the following renewable and low carbon resource in Sheffield:

[1] "Current installed capacity" referred to facilities that were operational or had planning consent

- Current capacity of 99 MW and 554 GWh[2] largely made up of biomass from agricultural arisings (straw) and energy from municipal solid waste and landfill gas.
- Potential electricity resource: 48 MW largely from commercial wind and solar PV.
- Potential heat resource: 91 MW largely from solar thermal and air source heat pumps.
- Potential significant contribution of co-generation of energy from commercial and industrial waste.
- Combined potential resource: 388 GWh annual generation.

2.4 Sheffield Policy

Sheffield's planning policies provide the basis for decoupling new development growth with carbon emissions. The Core Strategy adopted in 2009 sets out how:

- the city will develop spatially;
- different land uses will be located;
- the environment will be protected and enhanced;
- areas and buildings will be designed;
- places in the city will be connected through the location of new development and provision of transport.

As part of the Core Strategy, Policy CS65 on Renewable Energy and Carbon Reduction[3] includes renewable energy targets for the city. These appear to be based on the 'low' deployment scenario outlined by IT Power in 2006:

Renewable energy capacity in the city will exceed 12MW by 2010 and 60MW by 2021.

CS65 requires new significant developments[4]to meet the following requirements (unless this can be shown not to be feasible and viable):

a) Provide a minimum of 10% of their predicted energy needs from decentralised and renewable or low carbon energy; and

b) Generate further renewable or low carbon energy or incorporate design measures sufficient to reduce the development's overall predicted carbon dioxide emissions by 20%. This would include the decentralised and renewable or low carbon energy required to satisfy (a).

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[2] These total figures are taken from table 70 in Appendix B.19. The figures in the table for individual technologies add up to 59MW and 383 GWh but the totals shown above are as per the summary. It is not clear which figures are actually correct.

[3] http://sheffield-consult.limehouse.co.uk/portal/sdfcs/core_strategy/core_strategy?pointId=1233053235961

[4] Significant developments applies to both new-build and conversions of 5 or more dwellings (including apartments), or more than 500 sq.m. gross internal floorspace.

2.5 Revised Targets

SCC commissioned Arup in October 2013 to consider the driving objectives for Sheffield to be 'Environmentally Responsible and Resilient'. The aim of the study was to clarify existing targets; to examine the current performance of the city; and to develop a strategy for meeting the targets, providing examples of projects that might be implemented in the future.

The resulting strategy report, 'Towards and Environmentally Resilient Sheffield Strategy Report, Oct 2013' outlined in detail four targets in the following areas:

- Reduced city carbon emissions (within the scope of the LA)
- Reduced energy consumption for the City of Sheffield
- Increased energy produced via sustainable methods
- Increased adaptation and resilience

These targets were subsequently adopted by the city council in December 2013.

The targets relating to energy production are (in terms of total annual energy production):

- Solar PV: 12.75 GWh (including existing installations)
- Solar Thermal: 12.6 GWh
- Air Source Heat Pumps: 65.25 GWh
- Commercial (new[5]): 10.7 GWh (including wind, biomass and EfW)
- **Total (rounded): 100 GWh**

These targets were established by a largely top-down approach, taking a 1% proportion of national targets and/or looking at existing installation rates to establish estimates of achievable installations by 2020. The target of 100GWh annually equates to approximately 75-80MW of installed capacity.

2.6 Summary

Comparison with the IT Power and AECOM resource assessments would suggest that the new SCC target of 100 GWh per annum by 2020 is achievable.

> The current study is intended to help build an evidence base on which to achieve this target based on a bottom up approach, reviewing the available resource and identifying projects and/or sites for renewable energy production that could realistically be achieved in Sheffield.

As part of this study, Arup has reviewed the IT Power and AECOM reports, reviewed the constraints to development and provided updated estimates of available resource in Sheffield.

[5] Existing Energy Recovery Facility, E.On biomass plant and landfill gas plants are excluded from this figure.

3 Electricity Generation

3.1 Legislation

Legislation at UK and EU levels are the main mechanisms for reducing energy consumption and carbon emissions in the UK. Government has introduced a package of mechanisms to tackle climate change that are designed to encourage UK business to save energy and reduce carbon dioxide emissions. These include the Climate Change Levy (CCL), Climate change agreements (CCAs), the EU Emissions Trading System (EU ETS) and the Carbon Reduction Commitment Energy Efficiency Scheme (CRC).

3.1.1 Climate Change Levy (CCL)

CCL is a tax, introduced in 2001, levied on the supply of electricity, gas, liquified petroleum gas (LPG) and solid fuels supplied to businesses. Rates vary across energy types but do not reflect differences in fuel carbon content.

3.1.2 Climate Change Agreements (CCAs)

Climate Change Agreements (CCAs) allow eligible energy-intensive businesses to receive a discount from the Climate Change Levy (CCL) in return for meeting energy efficiency or carbon-saving targets.

The Environment Agency administers the current version of the CCA scheme which runs from 1 April 2013 to 31 March 2023. The current scheme allows participants to claim their CCL discount at the revised rate of 90% for electricity and 65% for other fuels.

3.1.3 EU Emission Trading Scheme (ETS)

The EU ETS is a cap-and-trade scheme for direct CO_2 emissions from energy-intensive facilities, introduced in 2005. A ‘cap’ specifies the total number of emissions allowed, set at 2,039 MtCO2 across the EU in 2013 for ‘fixed’ installations (such as power plants and other industrial installations). This will be reduced annually by around 37 MtCO2.

3.1.4 Carbon Price Floor

A tax (the Carbon Price Support Rate, CPSR) on fuels used for electricity generation, set so the combined carbon price including the ETS meets an increasing trajectory (£16/tCO2e in 2013 rising to £70 in 2030, in 2009 prices). The CPSR is set two years in advance, and varies by fuel according to carbon content.

3.1.5 CRC Energy Efficiency Scheme

The CRC Energy Efficiency Scheme is a mandatory scheme aimed at improving energy efficiency and cutting emissions in large public and private sector organisations.

CRC applies to all organisations which have:

- at least one settled half hourly electricity meter; and
- more than 6,000 MWh of qualifying electricity supplied on the settled half hourly market.

Some public bodies must participate in CRC no matter how much electricity they consume. These are known as mandated participants.

3.2 Incentives

Various incentives are currently available for the generation of renewable electricity that can have a significant impact upon the commercial viability of deploying a range of technologies.

3.2.1 The Renewables Obligation

The Renewable Obligation Order came into force in 2002 and is designed to encourage the generation of electricity from renewable sources. Electricity suppliers meet the Renewables Obligation by presenting Renewable Obligations Certificates (ROCs) which are issued for each MWh of renewable electricity produced. Suppliers can meet the obligation by either presenting ROCs issued for their own generated renewable electricity or by purchasing ROCs from other generators on the open market.

The RO scheme is planned to be phased out under proposals within the EMR. As of 2017 new generators will not be eligible to sign-up for the RO scheme and will instead have access to the FiT CfD scheme.

3.2.2 Feed-in Tariff

The Feed-in Tariff (FiT) scheme, introduced in 2010, provides incentives for the generation or low and zero carbon electricity from small installations. A range of technologies are supported and receive a payment for each unit of electricity generated from an eligible and accredited system. Systems up to a capacity of 5 MWe are eligible for the scheme.

Tariff rates are defined based on technology type and capacity and are originally defined on the basis of providing a return on investment of 5%-8%. The scheme is funded through a levy on electricity suppliers.

The FiT scheme has resulted in a significant take-up of renewable electricity generation across the UK. This take-up was significantly above the UK government's projections and resulted in a 'fast-track' review of tariff levels for PV systems.

3.2.3 Feed-in Tariff Contract for Difference

The Feed-in Tariff Contract for Difference (FiT CfD) scheme is planned to be introduced under the Electricity Market Reform. The scheme is intended to replace the RO as the primary mechanism for incentivising the generation of low and zero carbon electricity.

3.3 Wind Energy

In this study, wind energy technology of different scales has been categorised as shown in Table 1. Large and medium wind are the most common wind turbine classifications that attract investment due to the economies of scale leading to more favourable financial returns.

Micro and small wind energy schemes are primarily suited to domestic and certain industrial applications. They also have a considerably lower impact due to their relatively small scale in comparison to medium and large wind energy schemes.

	Power (kW)	**Tip height (m)**
Micro Wind	0-1.5	10-18
Small Wind	1.5-50	15-35
Medium Wind	50-500	25-55
Large Wind	500+	55+

Table 1 Wind turbine scales

3.3.1 Key Findings by IT Power

Constraints

The IT Power report considers the following constraints for large wind energy schemes:

- Wind speed - The NOABL wind speed database is a national database of wind speeds based on a combination of historic and calculated wind speeds. The NOABL database was used for a simple assessment, but is not accurate enough to be used in isolation for resource assessment purposes.
- Noise and shadow flicker – A 400m buffer zone from residential properties was allowed to reduce impact of noise and shadow flicker to an acceptable level.
- National Park – Large scale wind energy schemes are prohibited within the Peak District National Park. Large scale sites were discounted if they are closer than 1.5km from the National Park in order to reduce the impact that a wind energy development could have on the amenity of the National Park.
- Green Belt – It is expected that it would be difficult to obtain planning permission for developments in a large proportion of the green belt land within Sheffield.
- Local Topography – Sites that were identified as being sheltered by a large feature upwind were discounted due to the expected reduction in wind speed caused by other features.
- Sites of Special Scientific Interest (SSSI) – It is expected that it would be difficult to obtain planning permission for developments in a large proportion of the SSSIs within Sheffield.
- Common land – Potential access issues and agreements are likely to render common land unattractive for wind energy developers.

- Roads – For safety, a minimum buffer distance from major roads is required to allow for the turbine's fall over distance.
- Aviation – Aviation receptors can lead to planning objections and potential safety risks.
- Public Rights of Way – No wind turbine blades over sailing public rights of way.

Estimated resource

The estimated realisable large scale wind energy resource in Sheffield was estimated by IT Power (2021 high scenario) as:

- 12 MW installed capacity
- 26 GWh annual generation
- average capacity factor of 25%
- 2 potential sites

This was supplemented with an estimated small scale wind resource of:

- 7.9 MW installed capacity
- 6.9 GWh annual generation
- average capacity factor of 10%
- 4,600 potential sites

3.3.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Sheffield City Airport

Since the assessment was carried out by IT Power, Sheffield City Airport has ceased to function as an airport. This has removed one of the more significant constraints to large and medium wind energy schemes in the Sheffield City area. However, the proximity to domestic properties, Peak District National Park and Green Belt remain the more dominant factors within the city area.

Three additional sites are now considered suitable following the closure of Sheffield City Airport:

IT Power Ref	Location & Grid Reference	Potential Capacity (MW)	Notes
W4	Greenland SK 440425 89756	0.5	The removal of Sheffield City Airport opens this site up for development. Just within the 30km buffer zone of Doncaster Sheffield Airport.
W5	Handsworth SK 41132 87338	0.5	The site straddles Sheffield City Boundary and Green Belt. The removal of Sheffield City Airport opens

			this site up for development. Just within the 30km buffer zone of Doncaster Sheffield Airport.
n/a	Tinsley SK 40484 88482	2.5	The former site of Sheffield City Airport. Adjacent to green belt land. Potentially suitable for a single large wind turbine installation. Just within the 30km buffer zone of Doncaster Sheffield Airport.

Table 2 Additional Potential Wind Energy Sites

New developments

Since the IT Power report was issued in 2006, no new medium or large wind energy schemes have been installed or consented within the Sheffield City boundary.

Just outside the boundary of this study, there was a 900kW 99m wind turbine installed at the University of Sheffield Advanced Manufacturing Park. The proposed Sheephouse Heights windfarm to the north of the Sheffield boundary was refused planning permission in 2009. There is currently an application nearby for a medium wind turbine.

Whilst there are numerous potential micro wind sites around the city, uptake has been very slow with only eight small wind developments (>1.5–15kW) since the introduction of FiTs in 2010.

Methodology

The IT Power report uses similar constraints to the DECC Methodology, one notable difference is the difference in suggested residential buffers. The DECC Methodology proposes a buffer of 600 metres whereas the IT Power report proposes a buffer of 400 metres. From our experience of working with wind energy developers, a buffer of 400 metres is appropriate, based on the likelihood of an excessive effect due to noise.

The IT Power report also discusses the use of a 1.5 km buffer from the Peak District National Park. The 2011 Yorkshire and Humber report suggests a buffer of 2km for large wind energy developments in proximity to the Peak District National Park.

The DECC methodology suggests that a resource assessment should be based on the capacity of large turbines being 2.5MW. This figure has been adopted in this assessment compared with IT Power's assessment which uses 3 MW per turbine.

IT Power have used a robust methodology. Although there are recommended guidelines, there are no explicit regulations for how to assess the feasibility of different wind energy sites. However, it is worth noting that different wind energy developers have different perceptions as to the viability of wind energy sites. Therefore there is a possibility that a wind farm developer may deem it appropriate to develop a site that has not been recommended for development in the IT Power assessment.

3.3.3 Summary of Practical Resource

In line with the IT Power assessment, the least constrained sites with a potential for the development of a medium or large wind energy development are along the M1 corridor. The industrialised nature of the M1 corridor suggests that medium or large scale wind energy developments will have a lower impact on the industrial setting in the vicinity of the M1. A list of seven potential medium and large wind sites considered to be suitable is included in Appendix A. We have assumed that 50% of the sites prove to be technically infeasible or uneconomical to develop due to access, land availability, grid connection, environmental, permitting or other constraints.

The remaining realisable large and medium scale wind energy resource in Sheffield is estimated as:

- 6.0 MW installed capacity
- 13.1 GWh annual generation assuming a capacity factor of 25%
- 3-4 potential sites

Scenarios for development of large and medium wind to 2020 and 2030 are based on the following assumptions:

- 20% of the sites are developed by 2020
- 40% of the sites are developed by 2030

Due to low uptake since the introduction of FiTs, we have revised the contribution from small and micro wind as it is not expected that large numbers of these sites will be developed.

The estimated small and micro wind resource potential realisable by 2020 is:

- 0.5 MW installed capacity
- 0.4 GWh annual generation
- 80 sites

The estimated small and micro wind resource potential realisable by 2030 is:

- 1.1 MW installed capacity
- 0.9 GWh annual generation
- 180 sites

3.4 Hydropower

3.4.1 Key Findings by IT Power

Constraints

The main constraints to hydropower development identified in the IT Power report are as follows:

- Head - the height of the vertical drop of the water is a factor in calculating the potential power output. A minimum acceptable drop of around 1.2 metres was used.
- Access – there needs to be adequate access for construction equipment to reach the site, ideally the site would have vehicle access.
- Land availability – land for the construction of a powerhouse is important, this is a particular issue with sites in the city.
- Grid connection – Close proximity to a grid connection would reduce the cost associated with cabling infrastructure, and ensure that electricity generated can be utilised by the grid or nearby buildings. In order to reduce costs in this area, private connections to buildings can also be made.
- Flow – The flow rate of the river is another factor required for calculating the power potential; the Environment Agency sets the amount of flow that can be diverted for use by a hydropower scheme. The maximum flow that can be abstracted is 1.3 times the mean flow rate.
- Environmental impacts – The development of hydropower schemes needs to be sensitive to the impact it may have on the environment and ecology. Detailed ecological assessments need to be made. A fish pass will also need to be installed to ensure fish can migrate up and down stream.
- Climate change – Constraints that will result from this are unknown, it is thought that more floods are likely, which will impact a hydropower scheme in several ways: the head will be reduced during flooding due to high river levels and turbines may need to be shut down to minimise risk of damage to equipment. Wetter winters may mean more power potential, while during summer months there may be greater periods of low flows.
- Listed structures – this could restrict development on structures that have listed or ancient monument status.

Estimated resource

The estimated realisable hydropower resource in Sheffield was estimated by IT Power (2021 high scenario) as:

- 0.46 MW installed capacity
- 1.8 GWh annual generation based on an assumed average capacity factor of 45%
- 10 potential sites

3.4.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Methodology

IT Power assessed the site suitability using a Salford University study 'Evaluation of Hydro Sites in the UK', as well as carrying out site visits. 14 sites were identified as potentially suitable. Our assessment has built on the work carried out by IT Power as well as using the more recent study, 'Hydro Project Technical Report' carried out for Sheffield Renewables in 2008 (Sheffield Renewables, 2008).

A desktop study of the potential suitability of sites on the River Loxley has identified Hillsborough and Low Matlock Weir as potentially suitable. Recommendations have been made to install fish passes on both weirs by a Fish Pass Scoping Study (rather than alter the structure of the weir, which could make hydro unfeasible). A hydro scheme could complement these fish pass developments.

New developments

There have been two new hydropower developments since 2006:

- A 275 kW turbine has been installed at Ewden Water Treatment Works which draws raw water from More Hall Reservoir (site 24, IT Power report).
- A 120 kW turbine has been installed at Rivelin Water Treatment works (site 5, IT Power report).

Head

Loxley River (site 14, IT Power report) (actually Wisewood Weir) has been removed from the potential resources list. Recommendations have been made to alter the structure of the weir to allow fish to pass over, which could affect the viability of hydro here (Arup, 2013).

Land availability

Hadfield Weir at Meadowhall (site 22, IT Power report) has been removed from the potential resources list as is no longer suitable for a hydro scheme due to space constraints.

Water abstraction

In 2009, the Environment Agency (EA) published new Good Practice Guidelines for hydropower schemes. These have subsequently been reviewed and updated with the latest guidance published in January 2014 that came into force in April 2014 (Environment Agency, 2013). The latest guidelines vary from previous versions in that they set out new abstraction sensitivity banding. This sensitivity banding sets the acceptable water level for a given river and ensures that a hydropower scheme does not cause levels to go below this (Environment Agency, 2013). The new sensitivity banding means that some sites, that may have been viable in the past, will no longer be viable as less of the water can now be used. Vice versa, some sites may now be viable because more water can be used.

Fish pass requirements

The EU Water Framework Directive (WFD) introduced in December 2000 is aimed at improving the ecological quality of rivers and waterways, including fish populations. The EA Good Practice Guidelines now provide clearer guidance on how developers should meet the requirements of the WFD and other legislation such as the Salmon and Freshwater Fisheries Act and the Eel Regulations. Typically a fish pass will be required if the scheme were to make fish movement, up or down stream worse, or if fish passage is needed to fulfil the requirements of the legislation.

The EA does have a budget set aside for building fish passes but will pass on the responsibility to anyone wishing to develop a hydropower scheme, as a condition for granting the relevant licences.

High feasibility cost

While the IT Power report focused on the physical constraints, one of the main barriers to development of hydropower schemes is the high cost for site assessments and the large outlay of capital required to implement the project. Hydropower projects, more than most other forms of renewable energy technology have very site specific costs. This makes it more difficult to estimate costs for projects. In order to minimise cost and risk a three stage approach to initial work can be taken: initial site assessment, pre-feasibility and detailed feasibility.

Public perception

Public perception is another important factor to consider. There is often negative public opinion encountered during project development, often due to misinformation. There may be opposition to the development of hydropower schemes by local conservation groups, who actively oppose hydropower. Concerns are generally based around adverse effects on the local ecology and fish, as well as noise concerns. It is important to address these issues early on and engage with local communities in order to minimise the impact this negativity could have on the project. Reports that turbines maim fish are unfounded, strict EA guidelines ensure that turbines are screened so that fish aren't able to get in. Research has also shown that little or no damage to fish occurs if they pass through Archimedes screw type turbines (Mann Power Consulting Ltd, 2009).

3.4.3 Summary of Practical Resource

Most of the sites identified as suitable are located on the River Don, with some smaller potential on the River Loxley. Other rivers that flow through Sheffield are thought to have low potential due to practical constraints such as space, access and low head (River Sheaf and River Rivelin). There may be potential on smaller rivers off the main rivers, such as Storrs Brook, Blackburn Brook and Porter Brook.

Operational hydropower installations in Sheffield that have been identified in 2014 amount to:

- 0.62 MW installed capacity
- 2.09 GWh annual generation based on a combined capacity factor of 39%
- 3 sites[6] all owned and operated by Yorkshire Water

The remaining realisable hydropower resource in Sheffield is estimated as:

- 0.56 MW installed capacity
- 2.2 GWh annual generation assuming a capacity factor of 45%
- 14 potential sites

Scenarios for development to 2020 and 2030 are based on the following assumptions:

- 50% of the sites prove to be technically infeasible or uneconomical to develop due to access, land availability, grid connection, environmental, permitting or other constraints.
- 20% of the sites are developed by 2020
- 40% of the sites are developed by 2030

3.4.4 Assessment of Investment Potential

Due to the very site specific nature of hydro projects it is difficult to give a generalised view. Costs can be split into 4 areas;

- Civil works, relates to abstraction and return of water as well as building housing for the electrical equipment and compensating for any structural issues in the area of the scheme.
- Machinery, including turbines, generators and screening and any other plant required.
- Electrical works, wiring, grid connection and metering as well as control systems.
- External costs, licences, planning permissions, consultants.

Price per kW is likely to be somewhere in the range of £2,500 to £5,000 but could be considerably higher. Small schemes may be proportionally more expensive due to certain fixed costs mainly in relation to civil works. As an example of the variation in cost estimates and actual cost, the British Hydropower Association give cost estimates of between £250,000 and £500,000 for a 100kW scheme, Torrs Hydro in New Mills is a 70kW scheme and cost £300,000 and predicted costs for a scheme at Jordan Dam, Sheffield came in at between £850,000 and £1.3 million. A case study on Jordan Dam is included in Appendix E.

[6] Ewden WTW commissioned in 2002, Loxley WTW commissioned in 2004, Rivelin WTW commissioned in 2008.

3.5 Solar Photo-Voltaic

3.5.1 Key Findings by IT Power

Constraints

The main constraints to solar PV development identified in the IT Power report are as follows:

- Cost is the most fundamental barrier. The technology still requires a relatively high initial investment and payback period for many and access to finance remains a barrier for householders and companies. 'Rent a roof' schemes are available, where building owners benefit from the free electricity and the company who pay for and install the panels receive the FiT payments.
- Finding roof space that is south west to south east in orientation and that is shade free is important in order to give reasonable power output from the panels as will maximise the amount of useful light reaching the panel, a north facing panel would produce 40% less power in comparison to a south facing panel.
- Planning constraints, planning approval is required for buildings in conservation areas and listed buildings and could potentially be refused, especially if installations are on the front of buildings. Many other solar developments will be classed as permitted developments.

Estimated Resource

The estimated realisable solar PV resource in Sheffield was estimated by IT Power (2021 high scenario) as:

- 24.9 MW installed capacity
- 18.7 GWh annual generation based on an average capacity factor of 8.6%
- 9,060 potential sites

3.5.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Methodology

The IT Power report used GIS data to obtain an estimate on the area of suitable roof space for solar panels. We have compared this with the DECC methodology, which uses set assumptions for assessing potential capacity. For existing roofs, 25% of all domestic, 40% of commercial and 80% of industrial buildings are considered suitable for solar panels. Power potential is assumed to be 2kW for domestic, 5kW for commercial, and for industrial buildings is regionally dependant. For this reason there will be natural variations in results obtained, this aside there has been considerable change in the resource potential since the 2006 IT Power report due to technological improvement and ease of installation.

New developments

According to OFGEM FiT installation data, there were over 2,900 new solar PV installations registered in Sheffield up to between April 2010 and December 2013. These installations have a total installed capacity of nearly 10 MW.

Solar irradiance assumptions

The IT Power report gives irradiation levels (amount of useful light reaching the earth surface) for Sheffield of 941 kWh/m^2 and an optimum PV system in Sheffield would have a slope of 37 degrees to the horizontal, face south and produce 910 kWh per year per kW.

Figures obtained from the European Commission Photovoltaic Geographical Information System are slightly different; they state that Sheffield receives 1160 $kWh/m^2$of irradiation. An optimum PV system in Sheffield would have a slope of 38 degrees to the horizontal, face south and would produce approximately 850 kWh per year per kW.

A recent report from the University of Sheffield's Solar Farm team analysed data from actual installations in Sheffield and surrounding areas. The analysis indicated that average performance for the 529 sites studied was 871 kWh per year per kW (Taylor, 2014).

New building developments

SCC has provided up to date information on the numbers of domestic and commercial buildings within Sheffield based on data from 2013. Approximately 14,000 new homes were built in the period 2005/06 to 2012/13. This is very similar to the estimated growth indicated by IT Power.

SCC has provided figures that suggest that the gross deliverable supply of new homes is 4,481 over the period 2014/15 – 2018/19. Remodelled housing delivery, which takes account of areas where there are concentrations of housing sites, suggests that around 14,400 homes could be built in Sheffield over the period 2018/19 – 2025/26.

Sheffield Re-roofing Scheme

SCC is currently investing in a five year re-roofing programme for 17,000 properties across Sheffield's council housing stock. SCC is investigating the potential to install PV concurrently with the re-roofing programme. The number of potential roof tops in the re-roofing scheme that maybe suitable for PV is estimated at 5,000 properties. Typical quotes are £2,800-£3,000 per property.

Maturity of the Market

There has been considerable change within the PV market since 2006. Most notably the cost of panels has decreased significantly. As demonstrated in Figure 4, 2011 PV module prices were in the region of 4.5 times lower than those of 2006 levels.

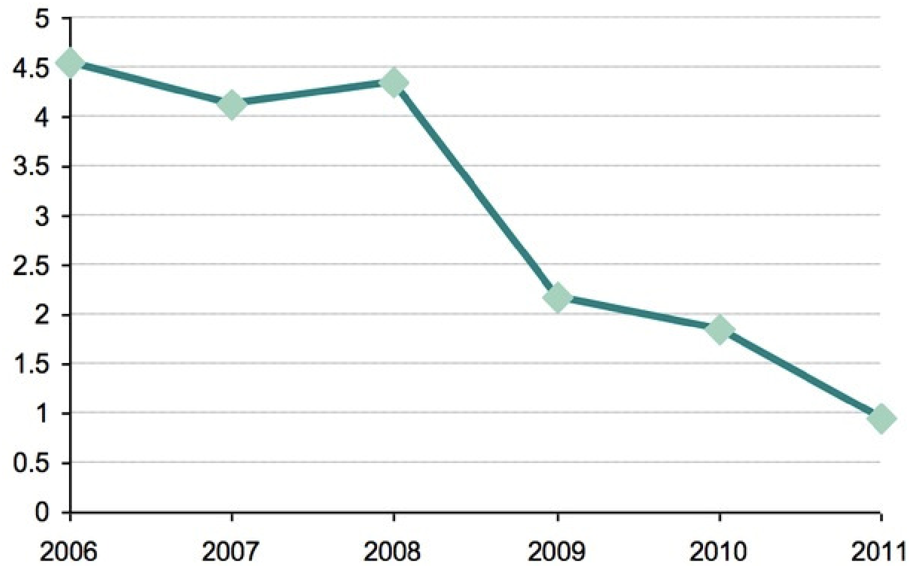

Figure 4 Chinese crystalline silicon PV module prices ($/kW), 2006-2011[7]

The dramatic price decrease has been attributed to several factors:

- Raw material costs have decreased considerably (£240 per kg of raw material in 2008 to £15 per kg in 2011)
- Panel efficiencies and manufacturing technology have improved
- Economies of scale and intense competition between manufacturers

Furthermore, the introduction of the FiT, has led to considerable growth within the solar installation market in Great Britain. Coupled with the reduction in PV module prices, the overall system installation cost has reduced significantly.

Solar in Sheffield

Although Sheffield may not seem to be an optimal environment for solar panels, having less irradiance (the amount of useful sunlight we receive) than other European countries, this is in fact beneficial for solar as the panels work more efficiently in Sheffield's colder climate and the lack of direct sunshine means sites can be less sensitive to orientation. High latitudes and altitude have also been found to benefit solar panel efficiency, Sheffield, being the most geographically diverse city in England, has a good range of altitude, this means there are fewer shading issues. Sheffield is also home to one of the main Solar panel testing facilities in Europe, Sheffield Solar Farm; they are at the forefront of solar panel development and provide a wealth of publicly available data on solar PV.

3.5.3 Summary of Practical Resource

Opportunities for solar PV installations are spread across the whole of the city. The relative ease of installation and proven performance of solar PV make this technology particularly attractive to potential developers. The FiT has increased

[7] http://theconversation.com/newsflash-solar-power-costs-are-falling-below-fossil-fuels-7215

the financial viability of solar PV considerably and this has stimulated significant growth of solar PV in Sheffield supported by a growing local capability in solar PV system design and installation.

Using the DECC methodology, 25% of the current housing stock (237,240) would be suitable for an average 2kW installation. By removing existing installations, it is estimated that a remaining 56,580 properties would be suitable for PV installation with a total installed capacity of 113 MW.

Allowing for some additional installations on existing and new commercial and industrial developments and new domestic properties, the total capacity for solar PV in Sheffield is estimated as 136MW.

Potential Uptake

The deployment potential of solar PV in Sheffield can be considered unconstrained by practical resource. It is therefore necessary to reduce the practical potential figure down to a figure that better represents what the expected uptake will be.

DECC forecasts that installed capacity of solar PV will be 10GW by 2020 for the whole of the UK. Sheffield currently contributes around 0.66% of national PV capacity. In order to maintain this ratio, Sheffield would need 66 MW installed capacity by 2020. This would require an acceleration of the build rate to five times the currently observed figure. It seems unlikely that this acceleration will be achieved and so a more conservative approach has been adopted for the purposes of this report.

Ofgem figures for the uptake of solar PV in Sheffield indicate that there has been an average of around 500 installations per year with an average capacity of 3.3kW. This excludes the large spike in numbers of installations in 2011.

We have assumed that the same rate of installations per year continues indefinitely. This is a rather simplistic approach, likely to result in an underestimate of installed capacity, but is in line with the methodology used for other technologies included in this report.

The estimated solar PV resource potential realisable by 2020 is:

- 21.4 MW installed capacity
- 16.1 GWh annual generation
- 6,400 sites

The estimated solar PV resource potential realisable by 2030 is:

- 38.2 MW installed capacity
- 28.6 GWh annual generation
- 11,400 sites

3.6 Summary of Electricity Generation

The vast majority of renewable electricity installations will come from solar PV. A small contribution will be made by wind and hydropower installations.

Figure 5 shows all of the IT Power deployment scenarios to 2010 and 2021, the actual installed capacity to the end of 2013 and future deployment scenarios to 2020 and 2030 based on revised estimates by Arup.

The development of the solar PV market in Sheffield is an excellent example of the FiT's success in achieving what it set out to do. The solar market is expanding and prices are falling. The same deployment rates have not been seen in the small and micro wind market however so these estimates have been revised downwards. Similarly, the contribution from large wind has been revised downwards to reflect a more cautious approach.

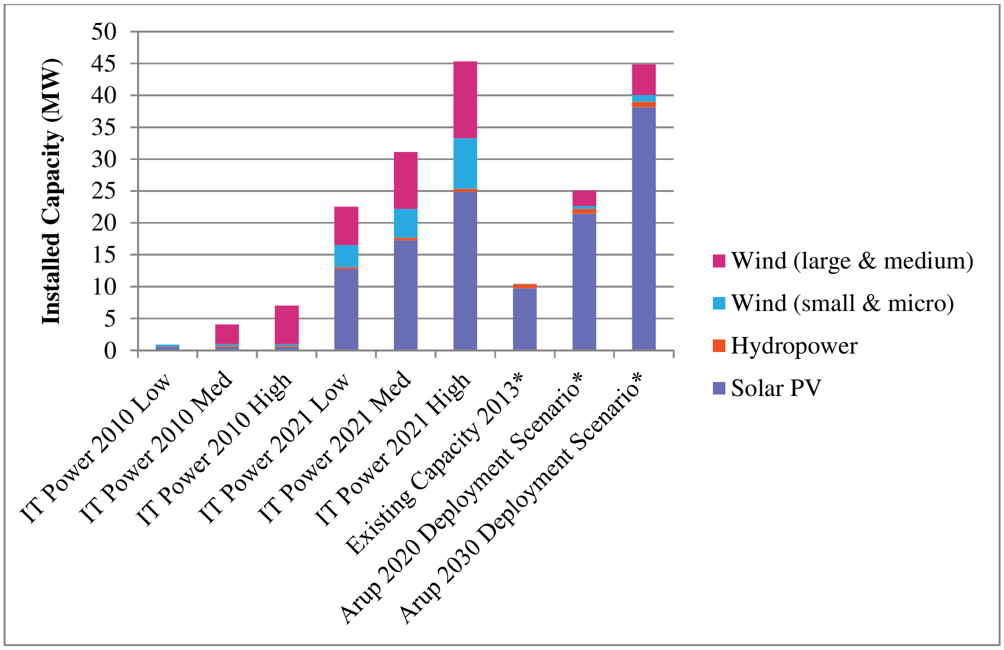

Figure 5 Renewable Electricity Installed Capacity Deployment Scenarios

*The existing installed capacity and future scenarios all exclude the contribution from the existing landfill gas plants totalling 2.14MWe installed capacity.

Figure 6 shows the annual generation expected from the same deployment scenarios. It can be seen that large wind and hydropower make up a bigger share of the annual generation due to their having higher capacity factors compared with solar PV.

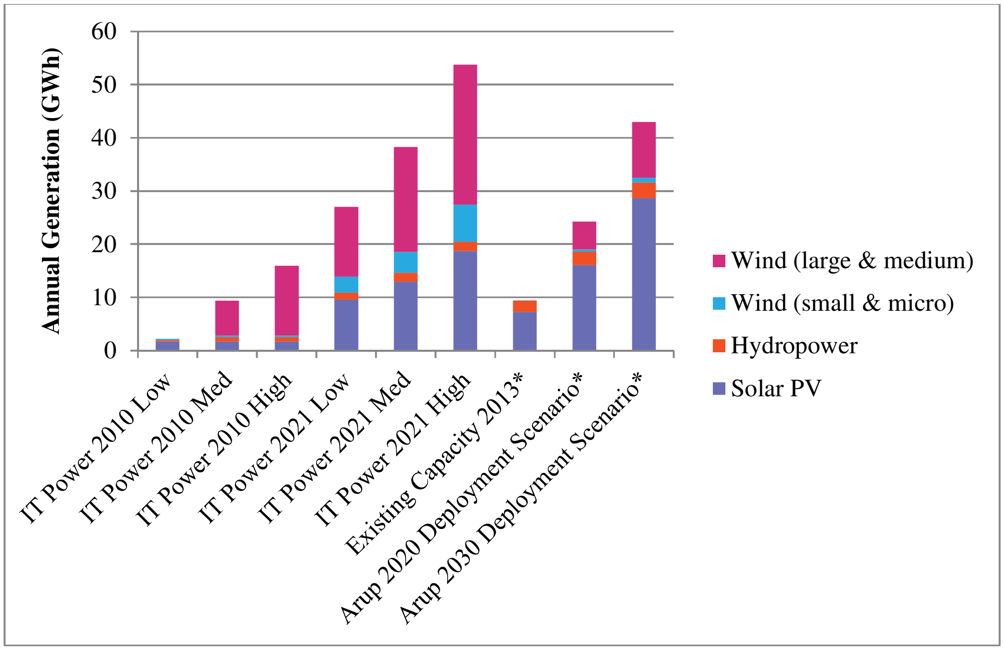

Figure 6 Renewable Electricity Annual Generation Deployment Scenarios

The remaining potential shown in Figure 7 demonstrates the continuing scope for growth in the PV sector in particular.

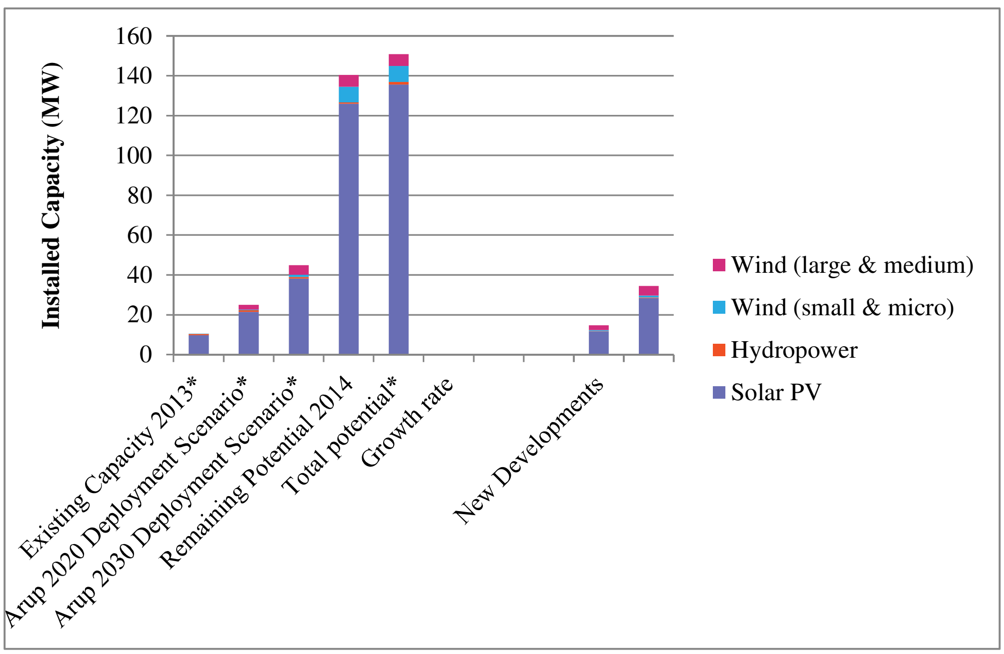

Figure 7 Remaining Potential for Renewable Electricity in Sheffield

4 Heat Generation

4.1 Context

Renewable heat is a relatively new commodity in the UK. Growth in the sector is being driven by the requirement to reduce overall GHG emissions. As nearly 50% of total energy demand in the UK is for heating purposes, yet less than 2% of heat production is renewable, the potential for growth is significant.

4.1.1 DECC's Future of Heating

The UK energy policy and legislative landscape remains uncertain, however this should not restrict local actions on energy matters. One area of certainty is the UK's action plan 'The Future of Heating: Meeting the challenge' published in March 2013 by the Department of Energy and Climate Change (DECC). The action plan seeks to ensure affordable, secure, low carbon heating in the nation's energy mix now and in years to come.

The action plan focuses on a number of key actions to encourage the move to low carbon heating alternatives and drive forward green growth across the domestic and non-domestic sectors. This includes:

- A £9million package to help local authorities get heat network schemes up and running in towns and cities across the country;
- £1million for the cities of Manchester, Leeds, Newcastle, Sheffield and Nottingham to help them develop heat networks in urban areas;
- 100 green apprenticeships to be funded primarily for young people in small scale renewable technologies, to start to stimulate growth in UK heat network supply chains;
- Up to £250k for a new first come first served voucher scheme for heating installers to get money off the cost of renewable heating kit installation training;
- A commitment to introduce a Renewable Heat Incentive (RHI) for householders in Spring 2014 and an extension to the Renewable Heat Premium Payment (RHPP) scheme until the end of March 2014 for small scale heat installations ahead of the launch of the RHI; and
- For non-domestic sectors, DECC has consulted on proposals for increased rates for 'Large' Biomass, Ground Source Heat Pumps and Solar Thermal.

4.1.2 Existing city-wide heat network

Sheffield already has one of the largest district heating systems in the UK, powered through an energy recovery facility (ERF) that burns the city's non-recyclable waste. SCC receives a profit share from the system and therefore expansion of the network is in the Council's interest. The extent of the network covers a large proportion of the city centre with legs extending further outwards as shown in Figure 8 below.

Figure 8 Existing city-wide heat network

The ERF burns 120,000 tonnes of municipal waste each year, producing up to 60MW of thermal energy and up to 19 MW of electricity. The steam that is created from burning the waste is converted to high temperature hot water for the district heating network whilst also producing electricity for sale to the National Grid.

The district heating network provides space heating and hot water to over 140 public buildings and 3,000 homes across the city. The business model for future delivery of heat or cooling over a much wider network is being developed with funding from DECC but upgrading and extension of the City Centre network is an early priority for major infrastructure investments. Extensions of the network into the Upper Don Valley via Kelham Island and to the Northern General Hospital through Pitsmoor are also under consideration.

4.2 Legislation

There is currently no legislation to regulate heat networks in the UK. Consumers connected onto a heat network have no protection therefore in terms of quality and pricing.

The Chartered Institution of Building Services Engineers (CIBSE) and the Combined Heat & Power Association (CHPA) have recently formed a partnership to underpin the quality of heat networks with the drafting of a code of practice. The partners believe that the development of a widely recognised code of practice for heat networks will support the spread of the technology by increasing the confidence of developers and investors. Government, as part of its support for the growth of heat networks, has also called on the industry to set out standards.

The partnership aims to follow the code of practice with training, accreditation and registration of engineers to enhance the quality of heat networks from design through to operation.

4.3 Incentives

Various incentives are currently available for the generation of renewable heat that can have a significant impact upon the commercial viability of deploying a range of technologies.

4.3.1 Renewable Heat Incentive – Phase 1

The Renewable Heat Incentive (RHI), introduced in 2011, provides an incentive to producers of heat and biomethane from renewable sources. The scheme has been set up to sit alongside the schemes for incentivising electricity generation from renewables, i.e. ROCs and FiTs. Phase 1 of the scheme is only open to non-domestic installations.

Under the scheme, generators of renewable heat are paid a tariff per unit of heat generated. The tariff level varies across technology type, installed capacity and date of installation and are payable for 20 years. The tariff rates have been defined on the basis of bridging the gap between conventional heating technologies and renewable systems.

Tariff rates and eligibility criteria for the scheme have been programmed to be conducted on a regular basis. This will ensure that the tariff rates reflect the current market conditions and the likely reduction in costs associated with greater technology development and take-up.

The RHI scheme is currently funded by the UK government and a fixed amount of funding has been made available for the scheme. As a result it is unlikely that the scheme will remain open to new entrants beyond the short to medium term.

DECC have recently announced that for the quarterly period starting on 1 January 2014 there will be no reduction to any tariff. The next tariff update will be published by 15 April 2014.

4.3.2 Domestic RHI – Phase 2

The Domestic RHI will be available from 1 April 2014. In the meantime, domestic renewable heat installations have been supported by a one-off grant known as the Renewable Heat Premium Payment.

4.3.3 Domestic Renewable Heat Premium Payments (RHPP)

The Renewable Heat Premium Payment is a one-off grant designed to help towards meeting the costs of installing renewable technologies in domestic properties, until the Renewable Heat Incentive (RHI) is introduced for domestic customers. The scheme was extended until the end of March 2014, ahead of the RHI scheme introduction.

As the RHPP is only available until March 2014 it is assumed that any potential readers would only be able to benefit from the RHI and not RHPP. For this reason, no further information is provided regarding the RHPP.

If an individual applies for RHI after already receiving a one off Renewable Heat Premium Payment, then the one-off payment will be deducted from the RHI payments.

4.4 Solar Thermal

4.4.1 Key Findings by IT Power

Constraints

The IT Power report considers the following constraints for solar thermal schemes:

- Solar water heating systems are most suited to buildings which require large quantities of hot water such as domestic premises, hotels, swimming pools and industry. Small hot water users will struggle to make a solar hot water system economically viable.
- One of the main constraints for solar water heating systems is the number of appropriate non-shaded south facing roofs and buildings in which solar water heating systems can be installed.
- Solar water heating panels can be either integrated or retro-fitted onto an existing building. Like Photovoltaics, solar water heating systems are ideally suited to south west through to south east facing roofs with most energy being gained from a south facing roof angled at 37 degrees.
- Solar thermal panels perform best in direct sunlight rather than passive light conditions such as those experienced on a cloudy day.
- It is important to have roof space which is not shaded for large periods of the day. In many cases, shading would make a project infeasible.
- Solar thermal systems are not typically suited to providing space heating in the UK as they require substantial collector area and an exceptionally large thermal storage to accommodate the thermal energy demands for the winter months.
- A typical domestic hot water system will require a collector area from 2.5 – 6 square metres.
- Solar water heating systems require a backup heating system to raise water temperatures when there is insufficient solar thermal radiation.
- As with photovoltaic systems, solar thermal collectors can be viewed as influencing the character of the areas or building so planning may be an issue.
- In recent years there has been a tendency to build houses with combination boilers and so do away with a hot water cylinder; this makes it difficult to install solar water heating systems as there may be insufficient space for the new solar store.
- Privately rented accommodation was not counted as part of the IT power calculation as it was regarded that they are unlikely to consider renewable technology.

Estimated Resource

The estimated realisable solar thermal resource in Sheffield was estimated by IT Power (2021 high scenario) as:

- 17.5 MW installed capacity
- 16.7 GWh annual generation
- 13,574 potential sites

This was based on the following assumptions for the typical capacity of installations:

	Large	Domestic
Assumed rated power (kW) per system	25	1.2
Assumed generation (kWh) per annum per system	10,000	1,200
Average Capacity factor (%)	21.9	8.8

Table 3 Solar Thermal assumptions used by IT Power (2006)

4.4.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Methodology

The IT Power report used the assumption that micro-generation is typically associated with a building. In order to estimate the practical resource of micro generation the number of buildings were sourced. The capacity estimation is based upon a percentage of the housing stock and the footprint areas of business and industry. The potential for large solar water heating systems was regarded as limited to swimming pool installations and greater emphasis was put on domestic installations. Of all the renewable technologies examined in this report, solar water heating is the least cost option and likely to see the greatest uptake.

We have compared the IT Power to that of the DECC methodology, which uses set assumptions for assessing potential capacity. It has been determined through the DECC methodology that each property type has different potentials:

- 50% of new domestic developments suitable
- 40% City Council buildings
- 25% existing social housing
- 80% business/industry/retails
- 25% owner occupied housing

	Industrial	Commercial	Domestic

Assumed rated power (kW) per system	25	5	2
Assumed generation (kWh) per annum per system	10,000	2,000	2,000

Table 4 Average generation capacity of an individual system; DECC (2010)

Latest Building Numbers

SCC has provided up to date information on the numbers of domestic and commercial buildings within Sheffield based on data from 2013. Estimates of future developments up to 2020 were also provided.

Maturity of Market

There has been a change within the solar hot water market since 2006. The large uptake in Solar PV has seen the market of solar hot water also increase, with suppliers and installers often offering hot water systems where PV may not be suitable.

- Economies of scale and intense competition between manufacturers
- The introduction of the RHPP and the impending domestic RHI tariff has meant that more installations are becoming economical viable.

4.4.3 Summary of Practical Resource

Opportunities for solar hot water systems are spread across the whole city. The relative ease of installation and proven performance of solar thermal systems make this technology particularly attractive to potential developers. The RHPP, non-domestic RHI and the impending domestic RHI has increased the financial viability of solar hot water and this has stimulated growth in Sheffield, supported by local capability in system design and installation.

From current stock the total practical solar hot water potential lies in the region of 115 GWh. SCC has provided figures that suggest that the gross deliverable supply of new homes is 4,481 over the period 2014/15 – 2018/19 increasing the practical potential to 119 GWh in this period. Remodelled housing delivery, which takes account of areas where there are concentrations of housing sites, suggests that around 14,400 homes could be built in Sheffield over the period 2018/19 – 2025/26. This increases the practical potential generation figure to 134 GWh.

Increasing Uptake

The new domestic RHI tariff that comes into place during 2014 is expected to increase the uptake of solar thermal systems throughout Sheffield. The tariff has come into place to help increase the economic viability of installations. Analysis from the Solar Trade Associate (STA) shows that a typical system could generate between £1350 - £2,350 over a 7 year period. In addition, average figures show that a customer will save up to £55 per year when using the system to replace a gas heating system and up to £80 per year when it is used to replace an electric immersion heating system. DECC predict that by 2030, if income keeps pace with inflation, gas prices will increases on average 18%, so savings on household heating bills per year could be even greater. Investing in a solar thermal system will also save on boiler servicing and help improve boiler lifetime. Northstar energy has provided a model that suggests that the majority of technical viable solar hot water systems will offer a discounted payback of between 6 and 15 years.

Potential Uptake

The deployment potential of solar thermal in Sheffield can be considered unconstrained by practical resource. It is therefore necessary to reduce the practical potential figure down to a figure that better represents what the expected uptake will be. Although most of this practical potential will have payback periods of less than 20 years (a system generally has a 25 year warranty), other technologies may prove more economically viable, thus slowing the uptake of solar hot water systems. With the introduction of the domestic RHI and the freeze on non-domestic RHI it is thought that solar thermal systems will start to become a more common installation choice.

It would be sensible to suggest that solar thermal systems may mirror the trend that solar PV systems experienced after the introduction of the feed in tariff scheme. Although it may be argued that solar hot water system require a more complicated installation process (possible boiler replacement and storage tank integration), they will generally incur lower capital costs than solar PV; making it a viable investment for a larger number of businesses and households than other technologies with larger upfront costs.

Ofgem figures for the uptake of solar PV in Sheffield have been averaged to predict the same likely take up of solar hot water systems in the Sheffield region:

- 1 industrial installation per year
- 2 commercial installations per year (based on 20% of the number of solar PV installations due to the assumption that fewer commercial properties will have sufficient hot water demand to make solar hot water systems an attractive proposition)
- 250 domestic installations per year (based on 50% of the number of solar PV installations to reflect the higher ‘hassle-factor’ involved)

Using the above figures and the average generation capacity of an individual system (DECC, 2010) it is possible to estimate both the expected installation capacity and generation per year; as summarised below.

The estimated solar thermal resource potential realisable by 2020 is:

- 3.7 MW installed capacity
- 3.6 GWh annual generation
- 1,800 sites

The estimated solar thermal resource potential realisable by 2030 is:

- 9.0 MW installed capacity
- 8.7 GWh annual generation
- 4,300 sites

4.5 Air Source Heat Pumps

4.5.1 Key Findings by IT Power

Constraints

The IT Power report considers the following constraints for air source heat pump schemes:

- Air source heat pumps use the surrounding air as their heat source.
- Heat Demand - The heat demand for the building in terms of total energy requirement, demand profile and heating distribution system.
- The advantage over ground source heat pumps is that they are easier and cheaper to install, while also requiring less space. In return their coefficient of performance is lower.
- Heating System - Like ground source heat pumps they best suited to lower temperature heating systems, such as underfloor heating.
- Due to the cost of retrofitting, underfloor heating is most suited to new builds. Radiators can be used, but they should be larger due to the lower delivery temperatures.
- Heat pumps respond slower to sudden temperature drops than conventional heating systems so it is required that the system analyses both external and internal temperatures.
- Back up **-** In periods of extreme cold a secondary heat source will be required as the heat pumps system will be unable to meet demand.
- Retrofitting Issues **-** ECO heat pumps (Sheffield) suggested air source heat pumps are relatively easy to install in new build situations. Retrofitting was concluded to be harder, and it was suggested that any system should be installed in parallel with the existing conventional system.
- Available electricity capacity for the Sheffield City Region. Any upgrades to current electricity capacity will incur significant capital costs.

Estimated resource

IT power did not include any estimated figures specifically for air source heat pump potential in Sheffield. It is unclear as to why they have not included any specific figures for air source heat pumps.

4.5.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Methodology

The IT power report does not estimate the potential for air source heat pumps in Sheffield.

It is possible to use the DECC methodology to estimate the potential for heat pumps in Sheffield. The DECC methodology doesn't look at individual types of heat pumps and suggests a regional assessment should be based on the premise that most buildings (existing and new build) are suitable for the deployment of at least one of the heat pump options.

The DECC methodology gives very broad ranges of the number of buildings suitable for heat pumps:

- 100% of all off-grid properties
- 75% of detached and semi-detached properties
- 50% of terraced properties
- 25% of flats
- No data is found for commercial

The DECC methodology states the following assumptions to be used when assessing the available resource potential:

	Commercial	**Domestic**
Assumed rated power (kW) per system	100	5
Assumed generation (kWh) per annum per system	113,500	13,620

Table 5 Average generation capacity of an individual ASHP system; DECC (2010)

Latest Building Numbers

SCC has provided up to date information on the numbers of domestic and commercial buildings within Sheffield based on data from 2013. Estimates of future developments up to 2030 were also provided.

4.5.3 Summary of Practical Resource

Opportunities for air source heat pumps are spread across the whole city. The RHPP, non-domestic RHI and the impending domestic RHI has increased the financial viability of air source heat pumps. Increased financial viability is expected to stimulate the interest in the technology, along with increased local capability in design and installation.

As discussed, the DECC report doesn't differentiate the types of heat pumps, and thus the practical resource estimation for new developments will include both ground source and air source potential.

SCC has provided figures that suggest 4,481 new homes will be built in the period 2014-2020; which would equate to around 14MW of heat pump potential or 36GWh of generation per year. Further to this, new housing developments are expected to be a minimum of 14,400 for the period 2020-2030, equating to a natural and technically accessible resource of around 45MW or 117GWh of generation per year. This sees the total natural and technically accessible resource for heat pumps from new developments in Sheffield total 59 MW, or 153GWh of generation per year. It is to be noted that some of this potential may already be realised, or currently under planning consent. By including all existing properties, the total potential could be over 83MW and 200 GWh.

AECOM suggest that the maximum, economically viable resource for the Sheffield for air source heat pumps stands at 21MW or 32GWh of generation per year.

Increasing uptake

The new domestic RHI tariff that comes into place during 2014 is expected to increase the uptake of air source heat pumps.

BERR suggests that an average air source heat system has the following cost implications:

- £5,000 for new build
- £7,000 for existing build (retrofit)
- £500/kW for non-domestic

Government estimated that for a semi-detached house off the gas grid in a rural location with a typical heat demand of 10,000 kWh/year, householders could receive about £500 a year in RHI payments for an ASHP. The Energy Saving Trust (EST) says that incomes could be as high as £1,350 a year for houses best suited to the installation of an ASHP.

Potential uptake

The deployment potential of air source heat pumps in Sheffield can be considered unconstrained by practical resource. It is therefore necessary to reduce the practical potential figure down to a figure that better represents what the expected uptake will be.

With the introduction of the domestic RHI it is thought that air source heat pumps will start to become a more common installation choice.

Given that there is no precedent for this technology, we have made an assessment of the likely uptake using a bottom up approach based on the following assumptions:

- 30% of homes are suitable for heat pumps
- 6% of those would be replacing a boiler in any given year
- 10% of those would consider renewable heat
- 70% of those would opt for an ASHP

Using the above figures and the average generation capacity of an individual system (DECC, 2010) it is possible to estimate both the expected installation capacity and generation per year; as summarised below.

The estimated ASHP resource potential realisable by 2020 is:

- 10 MW installed capacity
- 27.1 GWh annual generation
- 2000 sites

The estimated ASHP resource potential realisable by 2030 is:

- 24.2 MW installed capacity
- 65.9 GWh annual generation
- 4800 sites

4.6 Ground Source Heat Pumps

4.6.1 Key Findings by IT Power

Constraints

The IT Power report considers the following constraints for ground source heat pump schemes:

- The two key constraints of a ground source heat pump are the heat demand of the property and the availability of suitable land for the ground collection loop.
- Demand - Ground source heat pumps are best suited to larger buildings with good levels of thermal insulation. The overall demand of a building is very important; a domestic property might cost £2000 – 2500 per kW whereas for a large office building the cost may be as low as £1200 per kW.
- Land Available **-** An area of land next to the building is required to install suitable ground source loops and heat exchanger; these can be either horizontal or vertical. For a trench system the ground heat exchanger requires a minimum depth of 1.5m, with the exact amount of space required depending on the heating requirements of the property. A typical domestic system using a horizontal heat loop will require an area of 120-150% of the floor area of the house. A borehole system will require a depth of 15 up to 150m. Where multiple boreholes are required they should be spaced 3 to 5m apart.
- Back up **-** A ground source heat pump system will typically be designed to provide 80% of the heating requirements and 50% of hot water requirements with the remaining supplied by an auxiliary heat source.
- Ground Conditions - The ground conditions can be important; wet ground will equate to less pipe work. Generally the number of bore holes required will remain the same irrelevant of ground conditions. In general, only large commercial applications would require any thermal testing of the ground; at an anticipated cost of £1500.
- Heat pumps use electricity for their operation, with efficiency dependent upon the temperature of the supply temperature (determined by ground temperatures) and the temperature of the heating distribution system.
- Ground source heat pumps are particularly suited to low temperature heating systems as this maximises the efficiency of the system. The efficiency of ground source heat pump systems is measured by the coefficient of performance (COP); typical values are between 2.5 to 4. The higher end of this range is for the under-floor heating systems, as they operate at a lower temperature (30-35˚C) than radiators.
- Property age – Heat pumps are not generally applicable to pre-1980 properties. This is because older properties built to previous building regulations standards have higher heat demands, which would tend to make an installation of heat pump equipment impractical.

Estimated resource

The estimated ground source heat pump potential in Sheffield was estimated by IT Power (2021 high scenario). The IT power report assumes that the number of domestic ground source heat pumps would be limited relative to other technologies such as solar thermal and solar PV, and this has been reflected in the figures below:

- 32.7 MW installed capacity
- 74.1 GWh annual generation
- 3368 potential sites

This was based on the following assumptions for the typical capacity of installations:

	Large	**Domestic**
Assumed rated power (kW) per system	50	6
Assumed generation (kWh) per annum per system	113500	13620

Table 6 Ground source heat pump system assumptions used by IT power (2006)

4.6.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Methodology

The IT Power report uses similar constraints to the DECC Methodology, one notable difference is that DECC uses a much more generous figure for the percentage of new developments suitable for consideration.

The DECC methodology doesn't look at individual types of heat pumps and suggests a regional assessment should be based on the premise that most buildings (existing and new build) are suitable for the deployment of at least one of the heat pump options.

The DECC report gives very broad ranges of the number of new buildings suitable for heat pumps. It states:

- 100% of all off-grid properties
- 75% of detached and semi-detached properties
- 50% of terraced properties
- 25% of flats
- No data is found for commercial

In our analysis, we have simplified the DECC methodology and assumed that 50% of all domestic properties would be suitable for heat pumps. We have used the following assumptions to assess the available resource potential based on the DECC methodology:

	Commercial	Domestic
Assumed rated power (kW) per system	100	5
Assumed generation (kWh) per annum per system	113,500	13,620

Table 7 Average generation capacity of an individual ASHP system; DECC (2010)

Latest Building Numbers

SCC has provided up to date information on the numbers of domestic and commercial buildings within Sheffield based on data from 2013. Estimates of future developments up to 2030 were also provided.

4.6.3 Summary of Practical Resource

Opportunities for ground source heat pumps are spread across the whole city. The RHPP, non-domestic RHI and the impending domestic RHI has increased the financial viability of ground source heat pumps. This is expected to stimulate the interest in the technology, along with increased local capability in design and installation.

As discussed, the DECC report doesn't differentiate the types of heat pumps, and thus the practical resource estimation for new developments will include both ground source and air source potential.

SCC has provided figures that suggest 4,481 new homes will be built in the period 2014-2020; which would equate to around 14MW of heat pump potential or 36GWh of generation per year. Further to this, new developments are expected to be a minimum of 14400 for the period 2020-2030, equating to a natural and technically accessible resource of around 45MW or 117GWh of generation per year. This sees the total natural and technically accessible resource for heat pumps in Sheffield total 59 MW, or 153GWh of generation per year. It is to be noted that some of this potential may already be realised, or currently under planning consent. By including all existing properties, the total potential could be over 83MW and 200 GWh

AECOM suggest that the maximum, economically viable resource for the Sheffield for ground source heat pumps stands at 9MW or 16GWh of generation per year.

Increasing uptake

The new domestic RHI tariff that comes into place during 2014 is expected to increase the uptake of ground source heat pumps.

BERR suggests that an average ground source heat system has the following cost implications:

- £8,000 for new build
- £12,000 for existing build (retrofit)
- £1,000/kW for non domestic

The Government estimates that householders could make £1,400 a year from the RHI with an additional £120 of fuel and operating cost savings. The EST estimates the income to be higher, around £3,000 a year for houses best suited to the installation of a GSHP.

Potential Uptake

Practical resource for a micro generation technology where fuel supply is not an issue often appears much larger than what is actually economically feasible. Although most of this practical potential will have acceptable payback times, other technologies may prove more economically viable, thus slowing the uptake of ground source heat pumps.

Predicting the exact uptake numbers for the coming years is very difficult, with a number of factors directly influencing specific installations.

Given that there is no real precedent for this technology, we have made an assessment of the likely uptake using a bottom up approach based on the following assumptions:

- 30% of homes are suitable for heat pumps
- 6% of those would be replacing a boiler in any given year
- 10% of those would consider renewable heat
- 10% of those would opt for a GSHP

Using the above figures and the average generation capacity of an individual system (DECC, 2010) it is possible to estimate both the expected installation capacity and generation per year; as summarised below.

The estimated GSHP resource potential realisable by 2020 is:

- 1.4 MW installed capacity
- 3.9 GWh annual generation
- 385 sites

The estimated GSHP resource potential realisable by 2030 is:

- 3.5 MW installed capacity
- 9.4 GWh annual generation
- 692 sites

4.7 Biomass heating

Biomass heating can be implemented on a much smaller scale than biomass power production.

4.7.1 Key Findings by IT Power

Constraints

The key constraints identified by IT Power for biomass heating were as follows:

- Biomass Resource – The availability of locally source biomass fuel. The total estimate for fuel within a 30 mile radius of Sheffield City centre is 40,000MWh per year, enough to provide heating and hot water to around 2,200 homes.
- Clean Air Act – The use of biomass installations is restricted in some areas of the UK by the Clean Air Act 1993. Sheffield falls within a smoke control area and it is an offence to emit smoke from a chimney of a building, from a furnace or from any fixed boiler if located in a designated smoke control area. This means any biomass equipment to be installed in the Sheffield area will need to be approved for exemption by DEFRA, or Sheffield City Council will need to issue an exemption for the particular installation under its powers given by the Clean Air Act. Some biomass boilers are already DEFRA exempted, however, where testing is required, the approval process can take upto 6 months and cost upwards of £10,000.
- Access and Storage – The number of biomass heating installations is constrained by the number of buildings with suitable access for deliveries of fuel and space for fuel storage. Ideally, a wood chip store is designed so that wood fuel can be simply tipped into it, rather than requiring special equipment to blow chips into the fuel store. Access and storage restrictions is likely to rule out many city centre locations, however many schools, leisure centres, community centres, offices, warehousing and other building slightly further from the city are likely to be suitable.
- Infrastructure for fuel processing and storage – Local processing and storage sites will eventually be needed in Sheffield. The South Yorkshire Forest Partnership, together with several local authorities including Sheffield City Council are looking at possibilities.
- Funding available nationally and locally to assist with capital cost of equipment – Funding is available through the Low Carbon Building Programme. Sheffield City Council and Yorkshire Forward are actively supporting biomass heating locally.

Estimated resource

The estimated realisable biomass heating resource in Sheffield was estimated by IT Power (2021 high scenario) as:

- 25.7 MW installed capacity
- 45.1 GWh annual generation based on an assumed average capacity factor of 45%
- 275 potential sites

4.7.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Energy Crops

The IT power report suggested that under the Renewable Obligation the market for biomass and the uptake of energy crops would stimulate the uptake of energy crops by farmers. It was expected that energy crop numbers would increase beyond the year 2015.

Research carried out by Arup suggests that the uptake of energy crop farming has not been as popular as previously thought. Following a consultation with Natural England it was possible to conclude that the total claim area for energy crops schemes in the Sheffield area was 5.74 hectares. The entire scheme is formed of short rotation coppice. Applying the DECC methodology and a value of 10 odt/ha, the total yield is likely to be in the region of 57.4 odt per year. This is expected to increase by 10% from the year 2020, giving an annual yield of around 63 odt.

Sheffield Biomass Resource

The biomass resource can be split into 3 categories:

1. Woodland – The potential for biomass resource from woodland sources in the Sheffield region has not changed, thus use the IT power value of 7,183 odt/year for a radius of 30 miles from Sheffield City centre.

   DECC methodology suggest to apply a standard calorific value of 5MWh/odt for fuel sourced from woodland. This gives a total woodland resource of around 35,915 MWh/year.

2. Waste wood – No specific figures for the potential for biomass resource from waste wood are available. Applying a DECC methodology of a 1% increase per year gives a total annual yield that will fluctuates from 568 odt/year in 2014, increasing to 602 odt/year in 2020, increasing again to 666 odt/year in 2030.

   DECC methodology suggest to apply a standard calorific value of 5MWh/odt for fuel sourced from waste wood. This gives a total waste wood resource of 2,840 MWh/year in 2014, increasing to 3,010 MWh/year in 2020, and increasing again to 3,330 MWh/year in 2030.

3. Energy Crops – As discussed above, total of 57.4 odt/year.

   DECC methodology suggest to apply a standard calorific value of 3.5MWh/odt for fuel sourced from energy crops. This gives a total woodland resource of around 201 MWh/year.The energy crop supply chain is currently in its infancy and the market conditions are extremely variable. This makes long-term forecasting difficult.

	Estimated total resource (MWh)		
Source	**2014**	**2014-2020**	**2020-2030**
Woodland	35,915	35,915	35,915
Waste Wood	2,840	3,010	3,330
Energy Crops	201	201	201
TOTAL	**38,956**	**39,126**	**39,446**

Table 8 Estimated Biomass Resource within 30 miles of Sheffield City Centre

Regional Biomass Resource

When looking at fuel resource for biomass heating it is important to have a local source; this helps to increase the economic viability of projects. Therefore, for the purpose of this document the biomass for heating must be sourced from the area immediately around Sheffield (30 miles from city centre).

New Developments

Sheffield City Council has a good track record of operating biomass heating schemes, with the following schemes currently operational.

- **Callow Mount**. 500kW biomass chip boiler with gas-fired backup serving six tower blocks. The boilers were originally coal-fired and have been converted for natural gas and biomass use. The conversion was before RHI eligibility. The site also had a CHP engine which has since been decommissioned.
- **Carwood House**. 350kW biomass chip boiler with gas-fired backup. Installed before RHI eligibility.
- **Greenland in Darnall**. 1MW biomass chip boiler with gas-fired backup. The Council are investigating a possible connection to heat supply from the EOn biomass plant via the proposed Lower Don Valley connection. The biomass scheme will remain operating and receives RHI support. The boiler is fuelled by biomass chip but may be converted to pellets in the future to meet air quality requirements.
- **Sorby House**. An office block in Burngreave.

In addition, the Bernard Road Incinerator provides additional heat into the Sheffield District Heating network. There are also a number of schools with biomass boilers in Sheffield, for example, Forge Valley School.

SCC owns a woodchip depot at Kettlebridge operated by biomass supply company Forest Fuels Ltd who source wood from the local Grenoside Woods.

It is estimated that there is a total of around 6MW of biomass heating installed in Sheffield.

4.7.3 Summary of Practical Resource

The average UK home uses 18MWh per year for heating and hot water. With 39,446 MWh of fuel available, it is possible to suggest a boiler efficiency of 85%. This means that the total biomass fuel resource for Sheffield could provide heating and hot water for around 1,800 homes. In practise due to existing biomass schemes already operating in Sheffield, this is limited to around 1,200 more homes.

Increasing uptake

The new domestic RHI tariff that comes into place during 2014 is expected to increase the uptake of biomass boilers.

AECOM suggests that an average biomass heating system has the following cost implications:

- £9,000 for new build
- £11,000 for existing build (retrofit)

The Government estimates that householders could make £1,300 a year from RHI with a biomass boiler and an additional £100 of fuel and operating cost savings.

Potential uptake

In the short term, the deployment potential of biomass in Sheffield can be considered unconstrained by practical resource. It is therefore necessary to reduce the practical potential figure down to a figure that better represents what the expected uptake will be. In the longer term, the deployment potential of biomass heating will be constrained by the available wood fuel resource within a 30 mile radius.

With the introduction of the domestic RHI it is thought that biomass heating will start to become a more common installation choice, particularly for community heating schemes.

Our assessment of the deployment potential for biomass heating is based on a bottom up approach based on the following assumptions:

- 30% of homes are suitable for biomass heating
- 6% of those would be replacing a boiler in any given year
- 10% of those would consider renewable heat
- 20% of those would opt for biomass heating
- Total new installations constrained to 1,200 homes

Using the above figures and the average generation capacity of an individual system (DECC, 2010) it is possible to estimate both the expected installation capacity and generation per year; as summarised below.

The estimated biomass heating resource potential realisable by 2020 (including existing installations) is:

- 12.7 MW installed capacity
- 22.9 GWh annual generation
- 670 sites

The estimated biomass heating resource potential realisable by 2030 (including existing sites) is:

- 18.5 MW installed capacity
- 33.3 GWh annual generation
- 1,200 sites

4.8 Deep geothermal

4.8.1 Technology

A deep geothermal energy centre (heat or power) will normally consist of a surface plant connected to a number of wells drilled to depths of several kilometres. A common configuration is a doublet system (Figure 9) where one well is used to abstract hot water and the other to re-inject cold water once the heat has been removed at the surface. While "doublet" or even "triplet" systems (i.e. multiple well systems similar that that shown in Figure 9) are common in geothermal schemes, recent advances in single well system designs may make single well systems an attractive alternative as noted in Section 4.8.8.

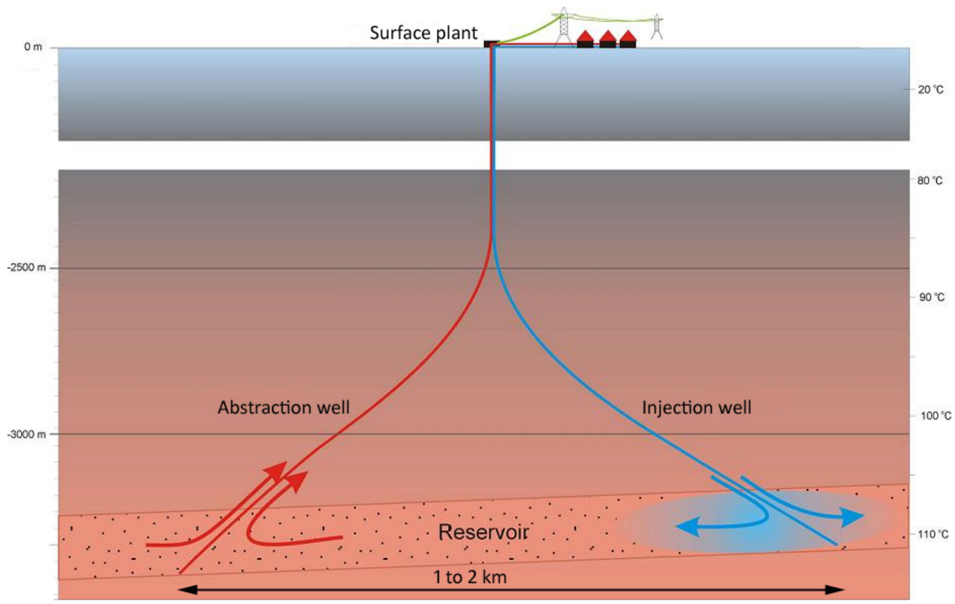

Figure 9 Typical 'doublet' geothermal energy plant.

The quantity of geothermal energy available at any location is dependent on:

- The temperature of the resource
- The rate at which fluids can be abstracted from the rock (determined by the geological properties)
- The ability to maintain the temperature and pressure of the resource (i.e. through strategic reinjection of water at an acceptable temperature)

Geothermal resources with temperatures between 70 and 115°C are normally considered appropriate for district heating systems. At higher temperatures, electricity generation may be considered, although the efficiency of electricity generation is relatively low. In countries where there is a heat demand (e.g. Northern Europe) many developers often make use of the geothermal resource to generation both heat and power (Combined Heat and Power - CHP) to increase the overall energy efficiency of the system. The balance between electricity and heat is a design variable and will depend on the temperature of the resource and the needs of the end user. A generalized CHP system is described in Figure 10.

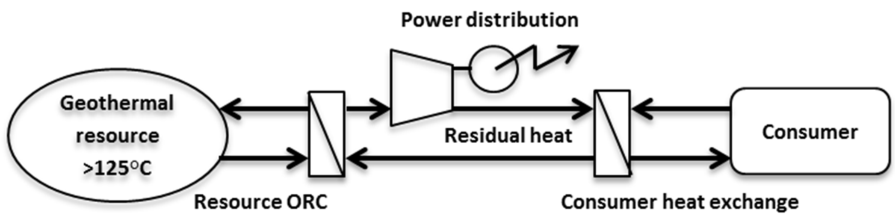

Figure 10 Schematic of typical combined heating and power system utilising geothermal resources.

Figure 3 illustrates a typical system for exploiting a geothermal resource for heat only.

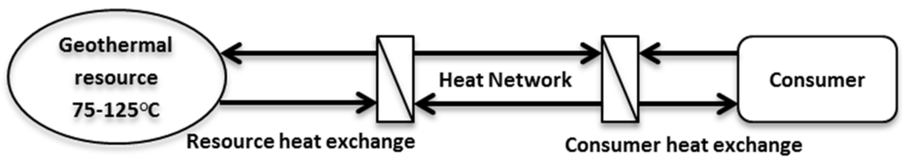

Figure 11. Schematic of typical "heat only" system utilising geothermal resources.

The following sections (4.8.2 and 4.8.3) describe and broadly quantify the geothermal resource in the Sheffield area.

4.8.2 Resource Assessment - temperature

The temperature of the resource is dependent on both local geological factors and the depth of the well. A deeper well will almost always be at a higher temperature than a shallow well but will cost more to drill. There is therefore a trade-off between the accessible geological temperature and economics. Further, at greater depths, it becomes increasingly difficult to achieve economic abstraction flow rates due to the higher compaction of the rock at depth.

Geological factors greatly affect both the temperature and the flow rate at a particular site. For example, there are many locations in Iceland where the temperature is very high at shallow depths (a high geothermal gradient) and the rocks have a high fluid content. This leads to a combination of high temperatures (between 50°C and 100°C/ km depth) and flow rates for each well drilled, which is why Iceland has a highly developed geothermal industry. In the United Kingdom, the geothermal gradient is much lower, being on average 25°C per km depth. This means that to achieve the same resource temperature, geothermal wells drilled in the United Kingdom need to be at least twice as deep as those drilled in Iceland. As noted, this usually also results in lower abstraction flow rates.

Assessments of the total potential geothermal energy resource in the United Kingdom vary. A recent study by Sinclair Knight Mertz (SKM) estimated that there is the potential to develop up to 9,500MWe of electricity and 100,000MWth of heat over the next 25 years[8]. Development to date has however been very slow, due to the greater availability of cheaper energy sources such as natural gas.

The geothermal gradient in the United Kingdom varies across the country, due to local geological factors[9]. The British Geological Survey has used existing data to map the approximate temperature at 1km depth across the country (Figure 12). According to this data, the temperature at 1km beneath Sheffield should be between 42 and 46°C. This is higher than the average for the United Kingdom and represents a geothermal gradient of between 30 and 34°C per km.

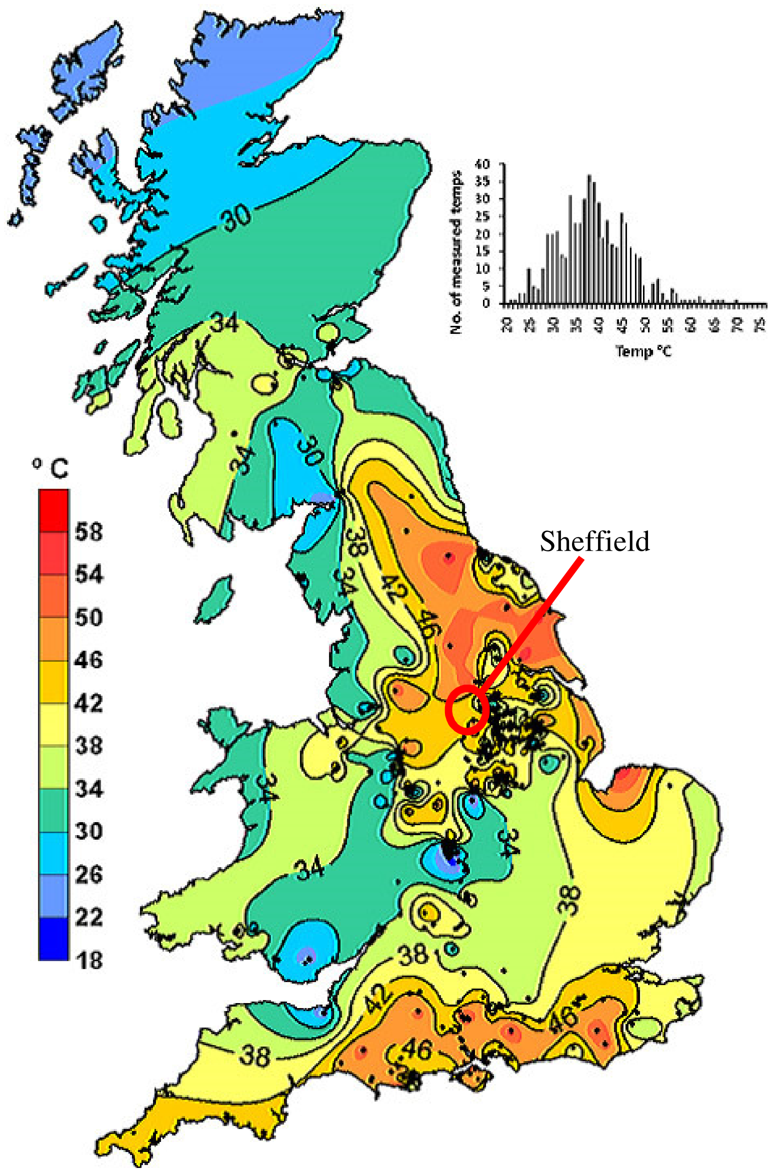

Figure 12 Estimated temperature at 1km (after British Geological Survey)[2].

[8] Geothermal Energy Potential, Great Britain and Northern Ireland. Sinclair, Knight Mertz, 2012.
[9] Busby, J., A. Kingdon, and J. Williams, 2012. The measured shallow temperature field in Britain, British Geological Survey.

To assess the overall resource potential for the Sheffield area, we have assumed the following constraints:

1. Minimum temperature required for electricity generation: 125°C
2. Minimum temperature required for heat distribution: 70°C[10]

For the range of potential geothermal gradients beneath Sheffield stated above, we estimate that to produce electricity and/ or heat, geothermal wells would need to be drilled to the depths noted in Table 9.

	Minimum depth (km) Gradient 30°C/ km	**Minimum depth (km) Gradient 34°C/ km**
Electricity production	~ 3.5	~ 4.0
Heat production	~ 2.0	~ 2.0

Table 9 Approximate well depth for heat/ electricity production beneath Sheffield

The data in Table 9 implies that to produce electricity from the resource beneath Sheffield a well would need to be drilled to a minimum depth of around three and a half kilometres. For direct heat production however, shallower wells drilled to around two kilometres may be sufficient (depending on the required delivery temperature).

These drilling depths are within the range of what would be considered technically feasible for a geothermal project. While the temperature at these depths may be sufficient for energy abstraction, the other principal constraint will be the achievable flow rate from the geological formations at these depths.

4.8.3 Resource Assessment - flow

The flow rate at a location is controlled by the type of geology at the site. For the Sheffield area, the deep geology is characterized in Table 10[11].

Depth	**Formation/ Comment**
Ground level to circa 800m	Coal measures overlying Millstone Grit
800m to approximately 1300m	Carboniferous Limestone, potentially fractured and karstic, good potential for flow
1300m to 3500m	Lower Palaeozoic rocks most likely to be Silurian (mixed sandy and muddy formations) overlying more argillaceous Ordovician rocks. Low grade metamorphic affected by Caeldonian deformation, tight matrix properties but potentially fractured at least in the sandier formations or in any volcanic or carbonate intervals. However, these fractures could be partly or fully sealed by mineral species and evaporites

Table 10 Summary of the expected deep geology beneath Sheffield

[10] We have assumed that up to 5°C is lost between the resource and the final heat delivery system which circulates at 60°C. This temperature would be at the lower end for a district heating system.
[11] BGS 1:50,000 map and regional guide for the Pennines

Overall, there is a large measure of uncertainty in the depth and thickness below the Carboniferous measures due to history of block faulting which means that some local areas will be structural ‘highs’ with thin deposits; while others will be basins with much thicker deposits. The nature of the deeper geological units mean that the flow rates for geothermal abstraction will be determined by the extent of fracturing and faulting within the rocks. It is extremely difficult to predict flow rates within fractured rocks until wells have been drilled and this will add significantly to the risk associated with any project. If fractures are filled (i.e. are non-conductive) or not laterally extensive where a well is drilled, the achievable flow may be negligible.

As there is no data for the achievable flow rates at the potential deep geothermal target depths beneath Sheffield, any estimates will have to be considered as highly speculative. However, for the purposes of calculating the potential resource we have included some flow rates per well which are assumed to be reasonably achievable (Table 11).

Scenario	**Flow rate per well (litres per second)**
Low scenario	3
Medium scenario	15
High scenario	40

Table 11 Possible flow rates from deep wells beneath Sheffield

4.8.4 Total resource

For the temperatures and flow rates discussed in the above sections, the total resource for the area has been calculated using the assumptions described in Table 12. The assumptions are based on the development of multiple geothermal projects in the Paris Basin[12] over the past 30 years.

Sheffield total area	**368**	**km^2**
Area of National Park (excluded from the total potential)	135	km^2
Total available potential area	233	km^2
Average well separation at target depth	1.5	km
Surface area required per project	7.1	km^2
Maximum number of projects for the given area	33	
Abstraction/ Injection temperature (electricity)	125/45	°C
Abstraction/ Injection temperature (heat)	90/45	°C

Table 12 Assumptions used to calculate the total potential resource

For the potential numbers of doublet systems noted in Table 12, energy generation scenarios have been developed for the low, medium and high flow rate cases assumed in Table 11. The results are shown in Table 13.

Scenario	**Heat (MWth)**	**Heat (MWh)**	**Electricity (MWe)**	**Electricity (MWh)**

[12] Miklós Antics, Geothermal district heating in the Paris Basin

Low	16.8	136,603	4.0	32,380
Medium	83.8	683,017	19.9	161,900
High	223.6	1,821,378	53	431,734

Table 13 Potential deep geothermal resource beneath Sheffield for different scenarios

4.8.5 Practical abstraction and project development

Based on our experience, there is often a significant difference between the potential geothermal resource and the actual resource that can be practically abstracted. This is due to a number of factors including the availability of potential drilling sites and the time taken to develop each project. This is often between 4 and 8 years, depending on planning and funding delays.

Given these logistical and other geological constraints (such as drilling delays due to unforeseen geologic conditions), we have estimated the potential resource abstraction that may be achievable over the next twenty years (Table 14).

For heat only generation from deep geothermal resources we assume that a single system would have a capacity ranging from 300 kW (for a single well system) to up to 5 MW (for a larger multi-well system). For a CHP deep geothermal system we have assumed a capacity of 1.5 MW of electricity (MWe) and 6.5 MW of heat (MWth).

	Low		**Medium**		**High**	
Period	MW Electric	MW Heat	MW Electric	MW Heat	MW Electric	MW Heat
2014-20	0	0	0	2.5	0.6	5.1
2020-30	0.6	2.5	1.2	10.2	1.8	20.3
	GWh Electric	GWh Heat	GWh Electric	GWh Heat	GWh Electric	GWh Heat
2014-20	0	0	0	20	5	40
2020-30	5	20	9	80	14	160

Table 14 Potential achievable deep geothermal abstraction scenarios

Note:
Annual production based on a 90% capacity factor.
Potential scenarios assume multiple plants are realized over the periods considered.

4.8.6 Risks and constraints

The principal constraint to the development of deep geothermal resources is exploration risk. This is the level of uncertainty associated with finding commercially viable flow rates and temperatures beneath the ground. Figure 13 shows the risk profile for a typical geothermal project over time along with the associated expenditure. Although this graph has been developed for electricity projects the same profile can be applied to heat only projects. It is clear that the early stages of any project incur relatively high risk and high expenditure, associated with the exploration phase.

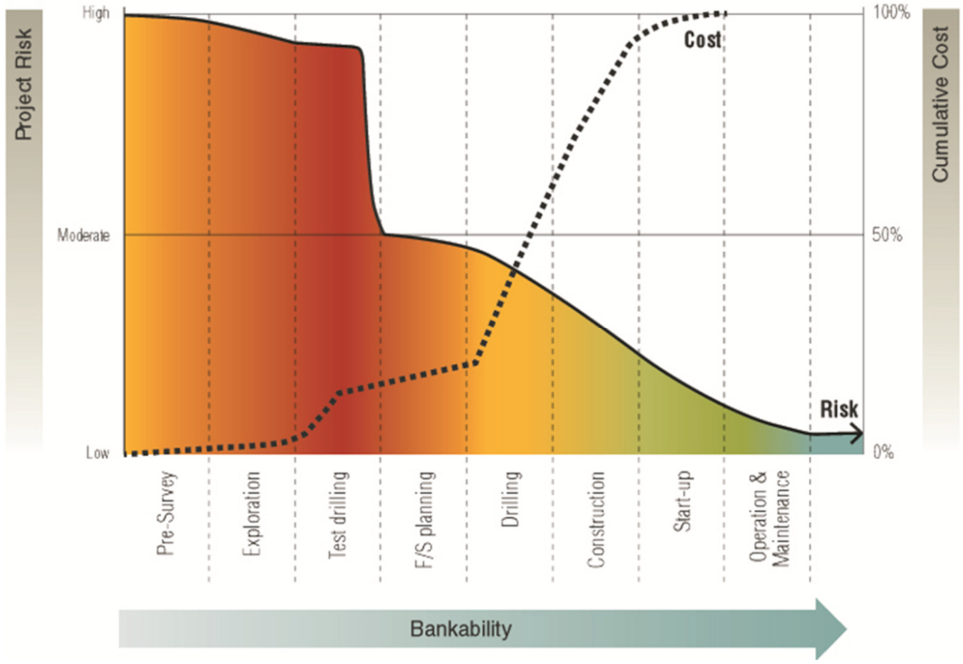

Figure 13 Geothermal project risk and cumulative investment cost (World Bank: Handbook on Planning and Financing Geothermal Power Generation)

Further to the exploration risk, there are also practical considerations for deep drilling in urban areas which can limit the number of potential sites that are available for drilling:

1. Noise restrictions

   Deep drilling is often a 24 hour process and, even with some of the latest rigs, significant noise levels are still generated at source.

2. Site access for rig delivery

   Deep drilling rigs are normally transported to the site in a multiple number of container loads and road access needs to be adequate.

3. Water supply

   Deep drilling will normally make use of water based drilling muds. Whilst drilling is underway, water requirements at the site are likely to be higher than mains water can supply

4. Industry maturity

   An additional constraint to the development of deep geothermal resources in the UK is the lack of an established industry. Any development will therefore meet with the challenges and delays typical of any emerging industry. This may further deter conventional, private investment.

4.8.7 Assessment of Investment Potential

Geothermal projects normally have long delivery times and high capital costs. They are therefore not attractive investments for those seeking short term returns. As a longer term investment, geothermal projects can make sense due to the relatively high capacity factor (plants often operate for over 90% of the time) and the relatively low operation and maintenance costs. Investment in a heat only project is also highly dependent on the bankability of the heat demand. A heat network normally needs to be in place (such as the existing network in Sheffield) and the heat user sufficiently credit worthy for a project to proceed.

Table 15 shows a number of different financial scenarios for a range of deep geothermal projects that could potentially be developed in Sheffield (using the temperatures and flow rates listed in the previous sections). The data suggests that under the current subsidy regime, only a heat project with a high flow rate per well or a CHP plant would achieve an IRR that would be considered acceptable to investors[13].

	Low	**Medium**	**High**	**Med (electric only)**	**CHP**
Flow Temperature °C	90	90	90	125	125
Return Temperature (elec) °C	N/A	N/A	N/A	45	70
Return Temperature (heat) °C	45	45	45	N/A	45
Flow Rate (l/s)	3	15	40	15	15
Peak energy (MWth)	0.6	2.8	7.5	0.0	1.6
Peak energy (MWe)	0.0	0.0	0.0	0.4	0.4
Percentage heat used	60%	60%	60%	N/A	60%
Electricity capacity factor				93%	93%
Annual heat use (MWh)	2967	14837	39565	0	8243
Annual electricity use (MWh)	0	0	0	2862	12776
Revenue RHI (£/MWh)	£50	£50	£50	0	£50
Revenue Heat sale (£/MWh)	£25	£25	£25	£25	£25
Revenue Strike Price (£/MWh)				£145	£145
Total Revenue (£m)	£222,553	£1,112,767	£2,967,380	£414,972	£2,470,756
Total Capex (£m)	17	17	17	20	20

[13] Renewable Heat Incentive of £50/ MWh and Strike Price of £145/ MWh for electricity

O&M costs (£000s per annum)	30	148	396	43	192
Plant lifetime (years)	25	25	25	25	25
Total Opex (£000s)	797	3987	10631	1153	5150
Total Revenue (£m)	£6.0	£29.9	£79.7	£11.2	£66.4
IRR	0%	5%	**16%**	0%	**11%**

Table 15 Estimated returns for a range of potential geothermal projects at Sheffield

4.8.8 Potential for advances in technology

Over the next decade there may be advances in drilling techniques or geothermal technology that enables projects to be developed in a faster timescale, at a lower cost or to reduce the exploration risk. The relatively rapid development of the shale gas industry in the United Kingdom will increase the deep geological knowledge base. Further, some of the deep wells drilled for shale gas may have the potential to be used as geothermal wells which may offer a cheaper alternative for development in certain areas.

We are also aware that the Department of Energy and Climate Change is also currently funding a so called 'deep geothermal single well' project that is testing a new type of system for heat only projects. This may prove to be a cost effective and relatively rapid method of deploying deep geothermal heat systems into the wider community.

4.9 Summary of Heat Generation

The potential for renewable heat in Sheffield is much higher than that of renewable electricity. Furthermore, the existing city centre heat network offers good potential for extension to incorporate future renewable heat installations. However, existing deployment rates are very low and there is considerable uncertainty in the potential growth of renewable heat.

The majority of renewable heat installations in Sheffield are expected to come from domestic installations. Air source heat pumps are expected to provide a large proportion of the renewable heat capacity. Biomass heating will also make a significant contribution, particularly through community heating schemes. Ground source heat pumps are not expected to play a major role due to space availability. A smaller contribution is expected to come from solar thermal. With the introduction of the RHI for domestic installations, it is expected that new installations will increase, although whether the incentive is sufficient to stimulate demand remains to be seen.

There is potential for deep geothermal heat to make a significant contribution. However, at present there are considerable exploration and financial risks developing this technology in the UK due to the relative lack of experience in the industry. Sheffield would be a good location to help build an evidence base for the technology due to the relatively good resource potential, existing heat networks which could be extended and the local supply of steel needed for borehole lining.

Figure 14 shows all of the IT Power deployment scenarios to 2010 and 2021, the actual installed capacity to the end of 2013 and future deployment scenarios to 2020 and 2030 based on revised estimates by Arup.

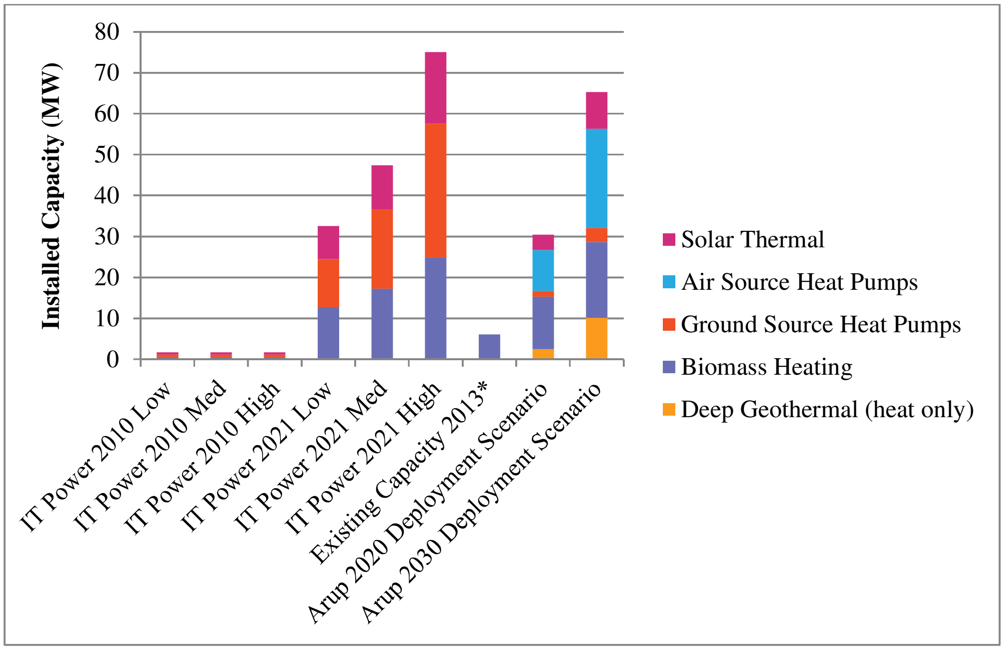

Figure 14 Renewable Heat Installed Capacity Deployment Scenarios

*The existing installed capacity and future scenarios all exclude the contribution from the Veolia Energy Recovery Facility.

Figure 15 shows the annual generation expected from the same deployment scenarios. Over the long term, the contribution from deep geothermal could be very significant due to high capacity factors of over 90%.

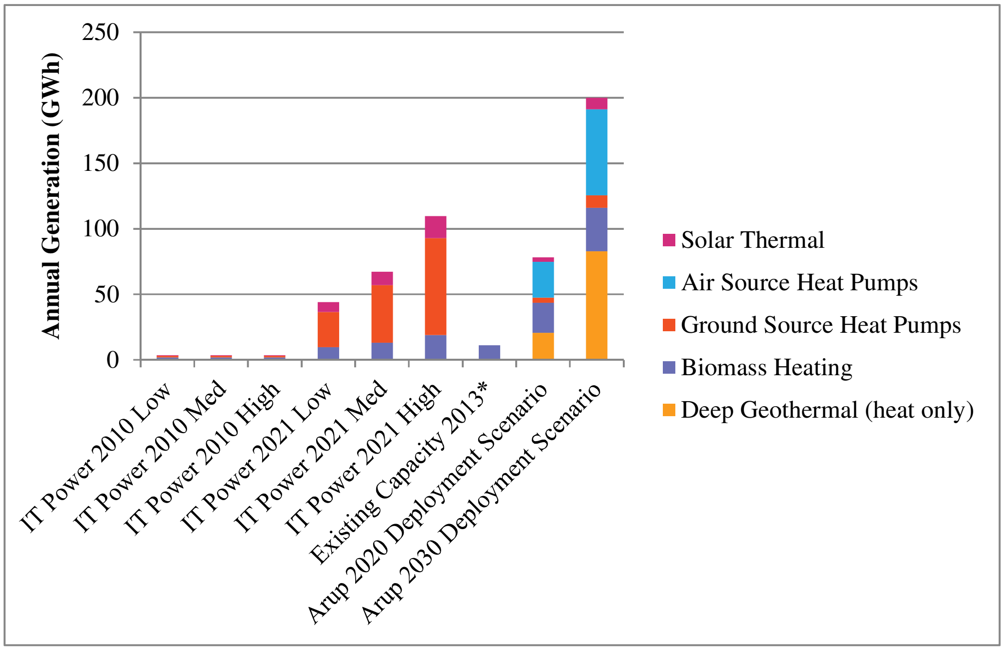

Figure 15 Renewable Heat Annual Generation Deployment Scenarios

The remaining potential shown in Figure 16Figure 7 demonstrates the enormous scope for growth in domestic micro-generation from air source heat pumps and solar thermal in particular. Deep geothermal could also have a very significant role to play.

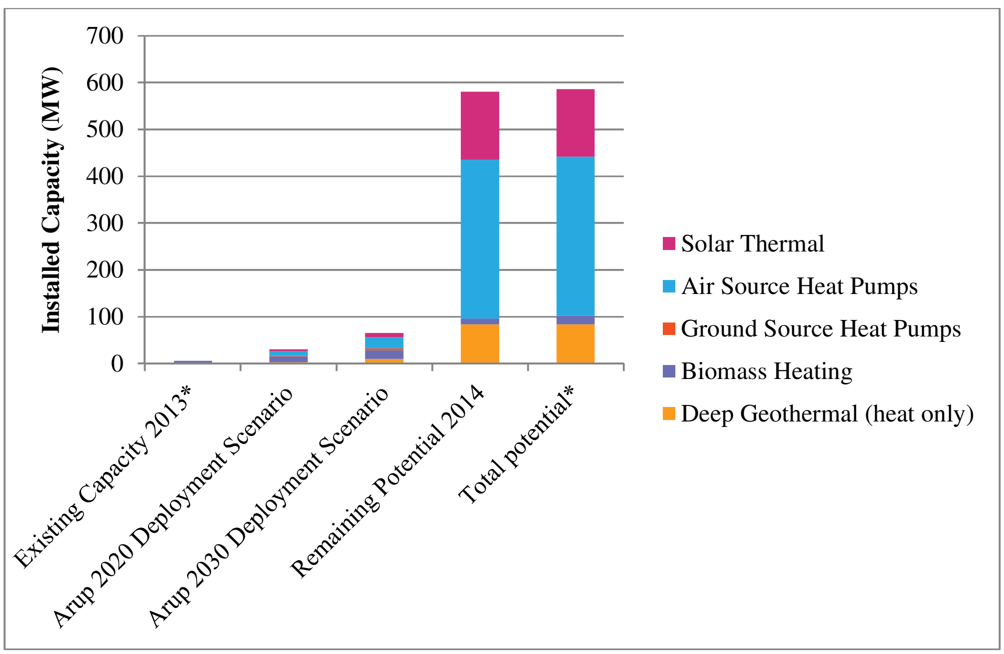

Figure 16 Remaining Potential for Renewable Heat in Sheffield

5 Co-generation

Cogeneration is a technique allowing the production of both heat and electricity. The heat is in the form of high pressure water vapour or hot water.

An electricity/heat cogeneration plant operates by means of gas turbines or engines. Natural gas is the form of primary energy most commonly used to fuel cogeneration plants. However, renewable energy sources and waste can also be used.

Unlike traditional power stations where exhaust gases are directly evacuated by the chimney, the gases produced by cogeneration are first cooled before being evacuated by the chimney, releasing their energy into a hot water/steam circuit.

Electricity/heat cogeneration installations can achieve energy efficiency levels of around 90 %.

5.1 EU Cogeneration Directive

The energy-saving potential of cogeneration is currently under-utilised in the European Union (EU). The purpose of this Directive introduced in 2004 was to facilitate the installation and operation of electrical cogeneration plants in order to save energy and combat climate change.

The objective of this Directive is to establish a transparent common framework to promote and facilitate the installation of cogeneration plants. This overall objective comprises two specific aims:

- in the short term, the Directive should make it possible to consolidate existing cogeneration installations and promote new plants;
- in the medium to long term, the Directive should create the necessary framework for high efficiency cogeneration to reduce emissions of CO_2 and other substances and to contribute to sustainable development.

5.2 Biomass Heat and Power

5.2.1 Key Findings by IT Power

Generating electricity from biomass is usually done on a larger scale than biomass heating in order to obtain the economies of scale to make the project economically viable. The key constraints are listed below:

- Biomass Resource – The availability of enough fuel to power the plant. A typical 2.5MW plant would require around 70,000 MWh of fuel per year. The Sheffield City region has insufficient resource and would rely on resources from further afield.
- Space available for the plant and fuel storage – This depends on the size of the plant. A typical 1.5MW plant will require a site area of around 0.5 hectares, with a plant of 40Mw requiring up to 5 hectares.
- Access for fuel deliveries – Regular fuel deliveries will be required. A typical 2.5MW plant would require 25 deliveries (using a 38 tonne lorry) per week
- Access for water cooling – As in fossil fuel power stations, water is required to cool and condense exhaust gas.
- Access for grid connection – The plant will require consultation with YEDL on the possibility of grid connection.
- National support for biomass power production – Capital grant could be available to help with start-up costs. In 2003 Bio-energy capital grants worth a total of over £25million were awarded for eight bio-power and CHP systems.

5.2.2 Changes to Constraints

Since the assessment carried out by IT Power in 2006, there have been a number of changes in the city and nationally which have changed the constraints to development. These are outlined below.

Technology Development

It was originally thought that small scale (less than 2.5MW) biomass heat and power installations would become more economically viable over the last 5 years; this has not, as of yet become the case. Very few projects can be classed as economically viable, and for this reason, co-generation installations smaller than 2.5MW have not been considered.

Fuel Supply

Installations of more than 2.5MW require a considerable fuel infrastructure, with around 70 GWh of fuel required per year. The entire Sheffield region is estimated to have less than 40 GWh per year.

For the reasons stated above, it can be assumed that any biomass heat and power projects that could be located within the Sheffield City region would require fuel that is sourced from regional, national or even international resource. This falls outside the scope of this work.

Regional Biomass Resource

As discussed in the economics section wood fuel resource for heating is limited to the area immediately around Sheffield, while fuel for power production could be sourced from a wider area. This is because a power plant would have much better access to transport links than smaller biomass heating installations.

No information on the regional and national potential was available at the time of publishing this document, however, it is expected that The Forestry Commission will publish the figures later in 2014.

New Developments

There has been one new biomass heat and power development since 2006:

- A 30MW biomass heat and power plant in nearing completion at Blackburn Meadows in Sheffield. Based on an availability of 90%, the plant will require about 180,000 tonnes of biomass per year.

This development suggests that the Sheffield area has only one other site that has been identified as suitable for a biomass heat and power development; Carbrook.

5.2.3 Summary of Practical Resource

IT power suggested that both the Yorkshire and Humber and the East Midlands region has a combined total biomass resource of 1,720GWh. It is expected that new figures for the United Kingdom, divided by region will be published later in 2014.

Further research will need to be carried out to fully understand how much of the regional and national resource is already contracted out to power plant such as Blackburn Meadows and Drax, and thus how that may have implications on the readily available biomass resource.

For the purposes of this assessment, it is assumed that no further large scale biomass heat and power developments are likely to be developed within Sheffield city.

5.3 Anaerobic digestion

Anaerobic digestion is already well-developed in the water industry with the main goal of reducing electricity consumption on site. There are also a number of non-sewage facilities operating within the UK, mainly using agricultural and commercial waste.

5.3.1 Overview

Anaerobic digestion (AD) is a widely-used process in the water industry for treating wastewater sludge. More recently, its application has extended to the conversion of waste organic materials to useful fuels, brought about by increasing concerns about the use of fossil fuels. This is demonstrated by the growing number of AD plants in the UK operating with agricultural, commercial and industrial feedstocks over the recent years.

Within the UK energy sector, biogas generated through AD has, for many years, been used as the prime fuel for Combined Heat and Power (CHP) plants. In Europe, particularly Scandinavia, biogas has been utilised as a prime source for biomethane production, with this biomethane subsequently being injected into existing gas networks. The biomethane can then be treated as natural gas where it can be used for domestic heating or fuelling vehicles.

5.3.2 Technology

Anaerobic digestion is a natural process where carbon-rich materials are broken down by micro-organisms to release methane-rich gas in the absence of air. The biogas is typically then used for electricity generation via CHP. The biogas can also be upgraded by removing the carbon dioxide and impurities to produce biomethane which can be injected into the gas grid.

A three-step chemical reaction occurs in the digester.

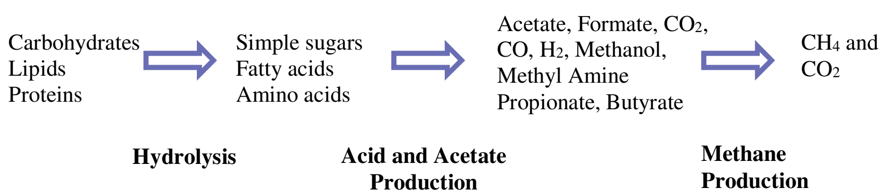

Figure 17: Chemical reactions in anaerobic digestion

There are two types of AD plants based on how it is operated. Mesophilic digestion takes place at around 25-34°C whereas thermophilic digestion operates at around 55-65°C. Mesophilic is usually favourable due to the biogas production being cost-effective.

There are also two types of AD plants that are based on the type of feedstock it can process: wet, which can handle feedstocks with dry solids between 10-15% and; dry, which handle feedstocks with 30% dry solids.

5.3.3 Applications

Combined Heat and Power

Biogas is typically used for electricity and heat production. The electricity is produced by the turbine and the exhaust heat can be recovered in a heat exchanger to generate heat or hot water.

Before it can be delivered to the CHP, moisture and H_2S must first be removed to avoid corrosion of metal parts in the CHP such as pipes and the engines. A flaring system is also required to burn the biogas safely when the CHP is unable to receive it.

Biomethane to Grid Injection

To produce biomethane, biogas can be upgraded using a number of processes. The upgrading system removes any moisture and impurities in the gas, such as CO_2, H_2S, siloxanes and other trace gases.

Having undergone gas cleanup, the biomethane will have to be analysed, metered and odourised before it is injected into the gas grid, to comply with the GS(M)R.

In order to provide security of supply to the local network it is essential that the BtG plant considers contingency measures in the event of AD failure. A Compressed Biomethane Gas (CBG) storage facility may be required, situated downstream of the gas clean up facility. This storage will also allow the BtG plant to flex the supply of biomethane to the network, in order to facilitate demand fluctuations.

The CBG storage facility can also be equipped with a filling station for fuelling natural gas vehicles. Filling stations operate as either fast-fill type, delivering fuel at a similar rate to that of traditional petroleum filling stations, or slow-fill system, used to refuel vehicle overnight.

5.3.4 Resource Assessment

A variety of organic material can be fed into an anaerobic digester to generate biogas. The potential feedstocks were classified into five groups: municipal solids waste (MSW), wood resource, energy crops, sewage and livestock waste.

Municipal Solids Waste (MSW)

In 2009, a total of 900,000 tonnes per year of general waste was estimated in the Sheffield Waste Management Report. Of this, 230,000 tonnes come from household waste and 670,000 tonnes from commercial waste. (Sheffield City Council, 2009)

There is a great potential to generate biogas from the waste collected due to the high organic content which can be harnessed by segregation of black bin waste. There is 150,000 tonnes of black bin waste collected each year and 41% of this is composed of garden and kitchen waste which could potentially be fed into an anaerobic digester.

By using an estimated 150 m^3 of biogas for each tonne of organic waste, of which 50% is methane, the city can potentially produce 9,225,000 m3 of biogas each year. (Esteves & Devlin, 2010) By feeding into an aerobic digester and CHP, a potential 14.2 GWh/yr of electricity and 28.4 GWh/yr of thermal energy can be generated.

Sheffield has already appointed Veolia to manage the waste through their Energy Recovery Facility. Therefore, it may be difficult to contend with the existing waste management programme should municipal waste be considered for anaerobic digestion.

Wood Resource

The IT Power Report provides an estimate of the woodland area within Sheffield in 2006 and is provided in Table 16 . It is assumed that there is no/minimal change in woodland area between 2006 and 2013.

Area of woodland (hectares)	Annual volume of fuel available (m^3/yr)	Mass of fuel available (oven dry tonnes/yr)	Energy from available fuel (MWh/yr)
66,506	266,023	7,183	39,903

Table 16: Available energy from woodland and forestry in Sheffield

Sawdust and woodchips have been used in anaerobic digestion and must be combined with a wet source (usually animal slurry) to lower dry solids content to around 10-12% to improve conveyability.

High fuel content makes wood resource from woodland and forestry a good choice for anaerobic digestion but it may inhibit the digester mixing system or float in the liquid phase which may obstruct the release of the generated biogas.

It is recommended that the woodland resource in Sheffield is better used for biomass heating. The electrical and thermal energy outputs have not been considered further.

Energy Crops

The Energy Crops Scheme (ECS) provides grants to farmers growing miscanthus and short rotation coppice for energy generation. The claim area for energy crops within the Sheffield district has been provided by Natural England and presented in Table 17. Each hectare yields around 16 tonnes of short rotation coppice (SRC) and each tonne can produce energy of 15 GJ. (CALU, n.d.) (Scragg, 2009)

Claim Area (hectares)	Crop type	Estimated Yield (tonnes/year)	Energy available from crops (GJ/year)	Energy from available crops (MWh/year)
5.74	Short Rotation Coppice	91.84	1,378	383

Table 17: Land area and potential energy from energy crops in Sheffield

Due to the small area dedicated to energy crops and minimal potential population who could benefit from this energy generated, this has not been considered further.

Sewage

Sewage is a great source of biogas and is already proven by the large number of AD facilities operating in many wastewater treatment works across the country. Sewage sludge is produced from settlement of wastewater and then treated in the AD to reduce microbial population to be safely used as soil conditioner. The biogas generated is typically used in CHP plants where any net electricity produced is exported, but not thermal energy.

Yorkshire Water manage the sewage AD facilities in Sheffield at Blackburn Meadows Wastewater Treatment Works. The site already imports sewage sludge from other sites in Yorkshire. It is assumed that access to municipal and industrial sewage is restricted to water companies and therefore, not considered further in this study. Packaged treatment plants that treat sewage elsewhere are assumed to be too small to be considered potential resource for AD use.

Livestock

The livestock population in Sheffield has been taken from the Revised 2009 County Authority breakdown for Livestock Populations and presented in Table 18.

Various sources were used to calculate annual livestock manure production, biogas yield and energy content for each animal type. (NNFCC, n.d.) (Kanwar & Kalia, 1993) (Menzi, Pain, & Smith, 1998) (Bradley, 2008) (Smith & Swanson, 2009) (Luostarinen, 2011). 50% was used as a conservative estimate of the methane content in all livestock waste.

The total electrical and thermal energy outputs presented below are based on the typical efficiencies that can be expected from a CHP. For electrical energy generated, 30% efficiency with 90% operational runtime was assumed. For thermal energy production, a combined 60% efficiency from heat dissipated by the engine and heat recovered from the flue gas.

Existing agricultural AD plants in the UK have an electrical capacity ranging from 100 to 9,500 kWe (mostly 500 kWe). However, it is not fully ascertained whether the smaller plants are demonstration plants which merely validate the concept but do not gain from the financial benefits from energy production.

Assuming that only 50% of the resource was feasible for development[14], this would result in a total resource potential for agricultural AD plants of:

- 0.55 MWe + 1.1 MWth installed capacity
- 4.3 GWhe/yr + 8.9 GWhth/yr annual energy generation
- 2 sites of around 300 kWe capacity each

[14] Using the same assumption as AECOM in the Yorkshire and Humber renewable energy capacity study

Animal Type	Units	Biogas Production (m3/tonne)	Average Waste Production per animal (tonnes/yr/unit)	Total Annual Waste Production (tonnes/yr)	Annual Biogas Production (m3/yr)	Average Methane Content	Annual Biomethane Production (m3/yr)	Energy Content per unit weight (MJ/kg)	Energy Content (kW)	Potential Electrical Energy Output (kWe)	Annual Electrical Energy Output (MWhe/yr)	Potential Thermal Energy Output (kWth)	Potential Thermal Energy Output (MWhth/y)
Cattle	9,998	20	14.5		2,899,420	50%	1,449,710		1,701	510	4,023	1,021	8,046
Pigs	1,672	20	3.2		107,008	50%	53,504		63	19	148	38	297
Sheep	39,234	28.4	1.66		1,849,648	50%	924,824		1,085	326	2,566	651	5,133
Goats	81	28.4	1.66		3,819	50%	1,909		2	1	5	1	11
Horses	621	-	8.5	5,278.50	-	-	-	4.73	792	238	1,873	475	3,745
Poultry	17,493	65	0.03		34,111	50%	17,056		20	6	47	12	95
TOTAL										1,099	8,663	2,198	17,326

Table 18: Potential electrical and thermal energy outputs from livestock population in Sheffield

5.3.5 Key Constraints

The IT Power Report does not discuss the key constraints in developing Anaerobic Digestion. The constraints discussed in this report consider the same ones discussed for biomass technologies and based on agricultural and wood waste AD facilities.

Access to capital

Access to capital funding is likely to be the biggest constraint to AD development in Sheffield. At the moment, most of the AD plants that have been developed are owned by larger producers who have the means of making large investments upfront. Small agricultural AD plants are technically and financially feasible but may struggle with large capital costs. This poses a challenge for smaller producers who do not have enough financial backing. There are incentive schemes that are designed to provide support to help initiate these projects and these are constantly being challenged to improve the chances of producers investing in AD technology.

Space availability

For an agricultural AD producing 300 kW electrical energy, a footprint of 2,500 m^2 is estimated. This includes the digester, the biogas holder, CHP and the pre-treatment units such as macerators and choppers.

A food waste facility will require around 4,000 m^2 for the dry digestion plant alone. It can be estimated that ancillary equipment such as CHP, gas holders and kiosk will be an additional 25% of the footprint.

Access for fuel deliveries

For agricultural plants, a slurry management system is typically already installed on-site which pumps the slurry from the barn/livestock shelter to a sump for direct feeding to the AD. The dry material (i.e. grass or maize silage) needs to be delivered to site on a regular basis. Storage facilities are recommended on site to reduce the cost for transport.

For food waste facilities, a complex management system would be required to separate food waste from black bins collected around Sheffield. It is anticipated that the food waste segregation facility is nearby the AD plant to reduce transport costs.

Water for cooling

Cooling water is required when running the AD with a CHP. Cooling water is also used in biogas upgrading plants that use water scrubbing system.

Grid connection

For electricity production via CHP, connection to the power grid is require if the site is a net exporter of electricity. Application for connection as a generator will need to be made to the distribution network operator (DNO) for Sheffield, Northern Power Grid.

If the energy producer desires to upgrade biogas to biomethane for grid injection, we recommend consulting with Northern Gas Networks who will facilitate network entry agreements (NEA) which involves assessing the nearest connection point and indicate the operating pressure as well as the cost to connect.

National Park

Development of AD schemes is likely to be prohibited within the Peak District National Park. Given that most of the agricultural waste is likely to be produced within the National Park boundary, this may significantly restrict development of AD from agricultural waste.

National Support

With the UK looking to increase the uptake of energy recovery from waste, the government is working to ensure that financial incentives available for AD such as the Renewable Heat Incentive (RHI), Feed in Tariffs (FiT) and Renewables Obligation Certificate (ROC), provide the revenue support that investors need. A growing market is already noticeable in the number of operational plants in the UK which has increased by over a third between 2011 and 2012.

Development of the existing AD facility together with provision of biogas upgrading, for export of biomethane to the gas grid, would also be supported at a local scale (financial support potentially from Utility Companies), for renewable energy in general and for energy from anaerobic digestion in particular.

It is also expected to see planning permissions eased, the cost of regulation to business reduced, subsidies to increase, awareness of AD in local communities improved, and increased overall support from the government and the Environment Agency (EA).

5.3.6 Summary of Practical Resource

The potential for AD in Sheffield is rather limited. Most of the available fuel sources are either already being used for energy production or would not be suitable. Importing fuel from outside the Sheffield City boundary would be necessary for any new medium and large scale AD plants (>500kWe).

Fuel source	Realisable Potential	Comments
Municipal Solid Waste	None	The existing Veolia Energy Recovery Facility is already using the available resource.
Wood Resource	None	The available resource is limited and would be better used for biomass heating
Energy Crops	Negligible	The demand for energy crops has not yet developed sufficiently to stimulate investment in the supply of energy crops throughout the UK. Land availability within the city is likely to continue to constrain growth in this area.
Sewage	None	The existing Yorkshire Water AD plant at Blackburn Meadows WwTW is already using all of the available resource.
Livestock	• 0.55 MWe + 1.1 MWth installed capacity • 4.3 GWhe/yr + 8.9 GWhth/yr annual energy generation • 2 sites	Based on an assumption that 50% of the available fuel resource was used.

Table 19 Summary of AD resource potential

5.4 Summary of Co-Generation

The remaining potential for renewable energy from co-generation in Sheffield is much lower than that of either electricity or heat.

The biggest contribution to renewable co-generation in Sheffield is expected to come from anaerobic digestion. This is likely to be limited to two or three sites only using agricultural waste or imported food waste. There may be some capacity for deep geothermal with CHP although heat only installations covered in the previous section are likely to be more economical to develop. There is no expected further development of biomass CHP. It is unlikely to be economically viable at small scales and the existing E.ON plant under construction will already be drawing wood fuel resource from a wide area to meet supply requirements.

Figure 18 shows all of the IT Power deployment scenarios to 2010 and 2021, the actual installed capacity to the end of 2013 and future deployment scenarios to 2020 and 2030 based on revised estimates by Arup.

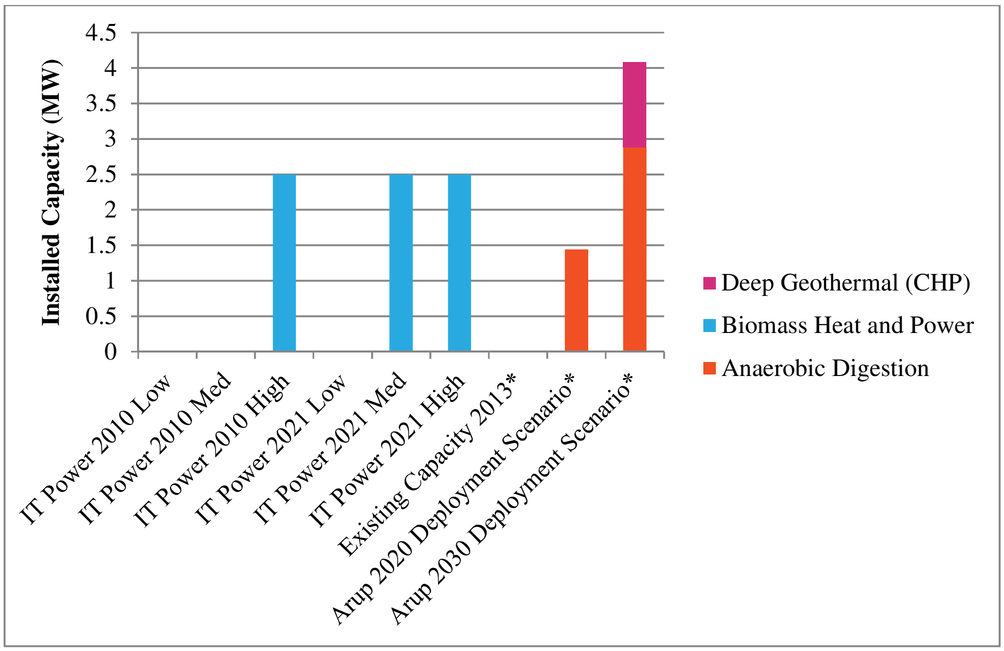

Figure 18 Renewable Co-Generation Installed Capacity Deployment Scenarios

*The existing installed capacity and future scenarios all exclude the contribution from the 25MW Blackburn Meadows Biomass Heat and Power Plant currently under construction by E.ON.

Figure 19 shows the annual generation expected from the same deployment scenarios.

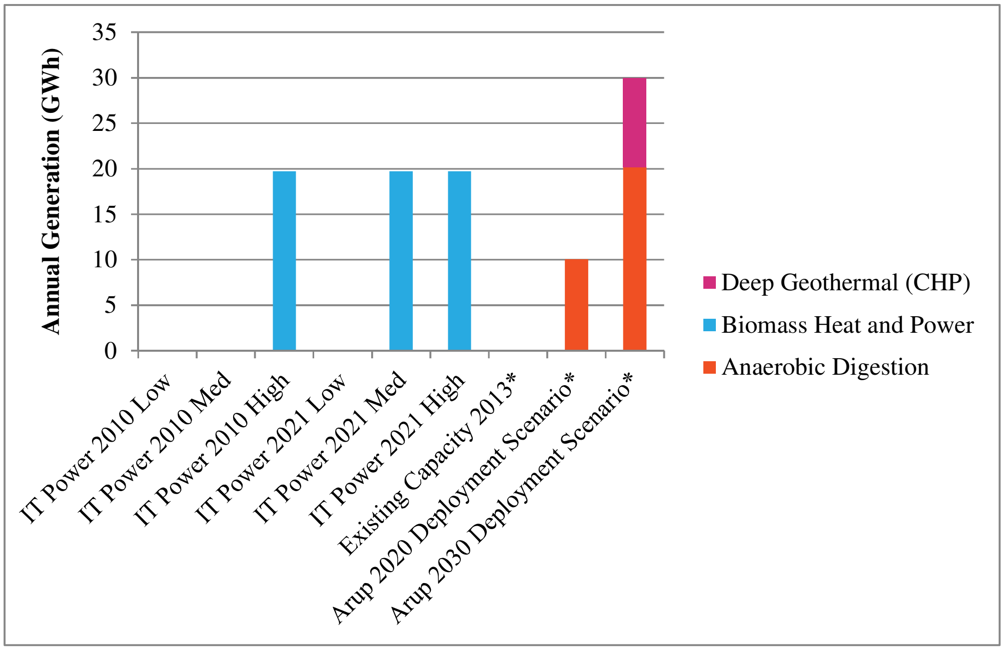

Figure 19 Renewable Co-Generation Annual Generation Deployment Scenarios

The remaining potential shown in Figure 20 demonstrates the potential scope for growth in deep geothermal. It should be noted that this resource would be shared with heat only geothermal plants.

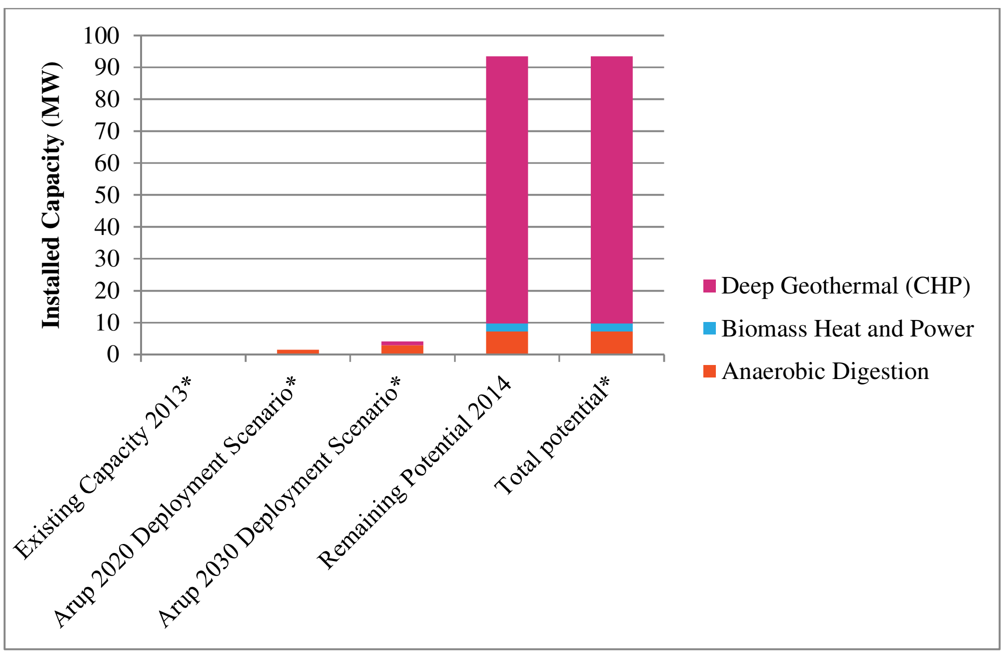

Figure 20 Remaining Potential for Renewable Co-Generation in Sheffield

6 Technology Comparison

A number of key drivers and criteria have been identified to allow comparison of the investment potential of different renewable energy technologies in Sheffield. All of the technologies under consideration have been assessed against these criteria in order to determine the most suitable technologies to further develop. Each technology is scored on a scale of one to five with one being the most favourable score. Where several different scales or applications of a technology apply then each different scale has been assessed separately.

Details of the drivers and criteria identified have been provided below. The technology comparison matrix is included in Section 6.4.

6.1 Investor Drivers

The investor drivers identified in the table below will be of interest to all types of developers as the key drivers of investment in a particular technology.

Criteria	Description
Investment Returns	The potential financial returns which may be derived from the technology options will be a key factor in determining which are likely to go-ahead. We have used simple payback as the key measure of this criterion.
Revenues & Savings	These will include revenues from the sale of electricity or heat; FIT or RHI payments; and savings from using the energy on site. Revenues generated from a project will need to be significantly higher than any operational costs in order for a project to be viable.
CO2 Reduction Potential	Carbon savings are a key driver in the development of renewable and low carbon technologies. Maximising CO2 reduction will help SCC to meet their short and long term targets as well as providing development incentives to potential developers.

Table 20 Investor Drivers

6.2 Investor Constraints

The investor constraints identified in the table below will be of interest to all types of developers as the key constraints to investment in a particular technology.

Criteria	Description
Availability of Sites	Availability of potential development sites and their location and spread within the city. Does the potential investor own the site?
Capital Cost	The total level of capital required in order to develop a project will be a key factor. Different sizes of investments will be attractive to different parties. Grant availability may be a key consideration.
Operational Cost	The long-term operational costs of each technology option must be sustainable and fall within a range which is manageable within available budgets. Ideally any operational costs will be covered by revenues generated from a project but there may still be significant cashflow implications.
Environmental Impact & Planning Approval	Technologies with minimal environmental impact are likely to be preferred over those which may have a larger temporary or permanent impact on the local environment. Environmental impact is likely to be a key factor in achieving planning permission for new developments.
Technology Maturity & Local Market	Mature, well developed technologies are considered to be lower risk than newer innovative projects. Where there are proven construction and operation track records this will reduce risks associated with programming and capital costs. Technologies for which products and services can be sourced within the local economy may be preferred.
Complexity of procurement and installation	How much would the development be dependent on partnering with multiple stakeholders? What is the appetite from these stakeholders to co-operate? How difficult is the installation process?
Maintenance & Reliability	Technology options that can demonstrate proven reliability with minimal maintenance requirements will positively affect the operational costs and revenues for the owner and/or operator.
Lifetime of Plant	The lifetime of the plant will be a key issue for investors when considering the return on investment and residual value after a period of years. This is particularly for micro-generation developments where householders may want to sell their property before an investment has been fully paid back.

Table 21 Investor Constraints

6.3 Social & Economic Drivers

The SCC criteria identified below are some of the key drivers for SCC in terms of supporting economic and social development.

Criteria	Description
Job Creation	Direct or indirect local job creation through the generation of a supply-chain and associated industries will be beneficial to the Sheffield economy. This may include selling products or services to other cities in the UK. Where jobs require significant training and may allow for a skilled workforce to develop will be preferred over unskilled jobs with non-transferable skills.
Innovation	The level of innovation associated with a technology option could help to position Sheffield as 'market-leaders', allowing for the development of new industry, skills and knowledge in the area and improving the marketability of future projects.
Local Energy Security & Resilience	The ability of a project to increase the energy security of the local area by reducing reliance on externally sourced fuels and feedstocks is likely to provide long-term benefits to Sheffield. Providing alternative options for the supply of energy will help to mitigate the risks of increased fuels costs.
Fuel Poverty Alleviation	Fuel poverty is a hot political topic and projects which provide opportunities to reduce fuel poverty across the local economy are likely to be supported by SCC.
Business Rates Retention	Technologies which attract business rate retention and/or other investment returns to SCC may be more attractive because SCC will be incentivised to support and "oil the wheels" of potential developments. For more information on Business Rates Retention refer to Appendix D.
Contribution to Targets	A single large project may have a much bigger impact on contributing to renewable and low carbon targets than many smaller projects. The impact of a cluster of small projects will be more significant than a single installation.

Table 22 SCC Social & Economic Drivers

6.4 Technology Comparison Matrix

		Investor Drivers			Investor Constraints								SCC Drivers					
	Typical capacity	Investment Returns	Revenues & Savings	CO2 Reduction	Availability of Sites	Capital Cost	Operational Cost	Environmental Impact, Permitting & Planning	Technology Maturity & Local Market	Complexity of procurement and installation	Maintenance & Reliability	Lifetime of Plant	Job Creation	Innovation	Energy Security & Resilience	Fuel Poverty Alleviation	Business Rates Retention	Contribution to Targets
Electricity Generation																		
Wind																		
Large	*500kW-2+MW*	3	3	3	5	5	1	4	2	5	2	3	4	4	3	5	2	3
Medium scale	*50-500kW*	4	3	3	4	4	1	4	2	4	2	3	4	4	3	5	3	3
Small	*1.5-50kW*	4	3	3	3	2	1	2	3	3	2	3	3	4	3	5	5	4
Micro	*0-1.5kW*	5	3	3	2	1	2	1	3	2	2	5	3	4	4	4	5	5
Hydropower																		
Low head run-of-river	*40-60 kW*	4	3	3	4	4	2	3	3	3	3	2	4	4	4	5	4	4
Low head run-of-river	*10-15 kW*	5	3	3	4	3	2	3	3	3	3	3	4	4	4	5	4	5
Solar Photo-Voltaic																		
Solar farm	*1 MW*	2	2	2	5	4	1	3	3	3	2	3	4	2	3	3	3	3
Portfolio of micro-installations	*50-100 kW*	3	2	2	3	3	1	2	2	2	2	3	1	2	3	3	4	4
Commercial site	*5 kW*	4	2	2	1	1	1	2	1	1	1	3	1	2	3	3	4	5
Single domestic installation	*2 kW*	5	3	3	1	1	1	1	1	1	1	3	1	2	3	3	5	5
Heat Generation																		
Solar thermal																		
Industrial site	*25 kW*	3	3	3	2	2	2	2	2	3	2	3	1	3	3	3	4	5
Commercial site	*5 kW*	4	3	3	1	1	2	2	1	2	2	3	1	3	3	3	4	5

	Typical capacity	Investment Returns	Revenues & Savings	CO2 Reduction	Availability of Sites	Capital Cost	Operational Cost	Environmental Impact, Permitting & Planning	Technology Maturity & Local Market	Complexity of procurement and installation	Maintenance & Reliability	Liftetime of Plant	Job Creation	Innovation	Energy Security & Resilience	Fuel Poverty Alleviation	Business Rates Retention	Contribution to Targets
Single domestic installation	*2 kW*	5	4	4	1	1	2	1	1	2	2	3	1	3	3	3	5	5
Air Source Heat Pumps																		
Commercial Air Source Heat Pump	*50-100 kW*	3	3	3	2	2	3	2	1	2	2	3	1	2	3	5	4	4
Domestic Air Source Heat Pump	*< 10 kW*	5	4	4	1	1	3	1	1	2	2	3	1	2	3	3	5	5
Ground Source Heat Pumps																		
Commercial Ground Source Heat Pump	*50-100 kW*	4	3	3	2	2	3	2	2	3	2	3	1	2	2	5	4	4
Domestic Ground Source Heat Pump	*10-20 kW*	5	4	4	1	1	3	1	2	3	2	3	1	2	2	3	5	5
Biomass heating																		
Biomass boiler with community heating	*100 kW - 1 MW*	2	2	2	2	4	4	2	2	4	4	3	3	2	2	1	3	3
Domestic biomass boiler	*10-50 kW*	5	4	4	2	2	4	2	2	2	2	3	3	2	3	2	5	4
Deep geothermal																		
Heat only	*300 kW - 5 MW*	4	3	3	3	5	3	3	5	3	4	2	3	1	1	1	1	2
Co-generation																		
Deep geothermal																		
CHP	*1.5 MWe, 6.5 MWth*	5	2	2	3	5	4	4	5	4	4	3	3	1	1	1	1	1
Biomass Heat and Power																		
Medium scale gasification CHP	*2.5-5.0 MW*	4	1	1	5	5	4	5	4	5	5	3	2	2	2	1	1	2
Anaerobic digestion																		
Agricultural Waste AD - 20,000 tpy	*300kWe*	4	2	2	2	4	4	4	3	3	3	3	3	3	2	4	4	4
Imported Food Waste AD - 50,000 tpy	*2.5MWe, 3.3MWth*	3	1	1	5	5	5	4	3	5	4	3	3	2	2	2	2	2

7 Delivery Mechanisms

The aim of this section is to provide an overview of the broad options for delivering energy projects and, in particular, the roles and responsibilities of the parties that are generally involved.

Energy projects can be grouped according to their method of service provision and their form of ownership:

- **Services** may be offered to the public through individual supply agreements, or be tailored to meet the requirements of specific customers ('bespoke' provision).
- **Ownership** and operation of the assets used to provide the service may be by a commercial company specialising in the field, or a Special Purpose Vehicle (SPV) created for the purpose, or the assets may be owned by the sponsor, who could be a developer, landowner, local authority or customer.

A range of delivery models and mechanisms have been used in the delivery of renewable energy projects across the private and public sectors in the UK. Project delivery models for energy projects vary widely depending upon the drivers for the project and the parties involved. Delivery models can be classified generally into three main types:

1. **Type 1:** Private Ownership
2. **Type 2:** Joint Ventures, partnerships and SPVs
3. **Type 3:** Municipal ownership

Other delivery mechanisms include:

1. **Type 4:** Social Enterprise
2. **Type 5:** Community Interest Companies
3. **Type 6:** Energy Service Companies
4. **Type 7:** Delivery by local authority
5. **Type 8:** Trusts

The most suitable option will depend upon intentions and resources with regards to income generation, technical expertise, commercial expertise, appetite for risk, availability and cost of finance, projects goals and profit making and distribution.

More detailed for each of these delivery mechanisms is provided in Appendix C.

8 Case Studies

Three case studies have been investigated to provide an insight into the types of projects available in Sheffield and their drivers and constraints. The case studies were based on

- Jordan Dam Hydropower Scheme being developed by Sheffield Renewables
- Lower Don Valley District Heat Network, E.ON
- Heating Social Housing, Sheffield City Council Housing
- Beighton Closed Landfill Site, Sheffield City Council

Details of these case studies are provided in Appendix E.

9 Conclusions

SCC has committed to a target of annual generation from renewable sources of 100 GWh per annum by 2020. The 2020 deployment scenario developed as part of this study would indicate that this target is achievable. The total annual generation from all technologies is estimated at 113GWh per annum by 2020. This is based on the growth rate assumptions listed in Section 10.1.

The total renewable energy capacity in Sheffield and deployment scenarios to 2020 and 2030 are summarised in Table 23 and Figure 21.

	Number of Sites	Installed Capacity (MW)	Annual Generation (GWh)
Existing Capacity 2013	2,940	16.5	20.4
SCC 2020 Target			100
Arup 2020 Deployment Scenario	11,300	56.9	113
Arup 2030 Deployment Scenario	22,900	114	273
Total Resource Potential	194,000	752	2,520

Table 23 Summary of Total Renewable Energy Capacity in Sheffield

The total estimated total long term resource potential for renewable energy generation in Sheffield is nearly 10 times the 2030 deployment scenario. This assumes that all of the available resource was economically and practically viable to develop. In practise, deployment rates of micro-generation will be the most significant constraint to continued growth beyond 2030.

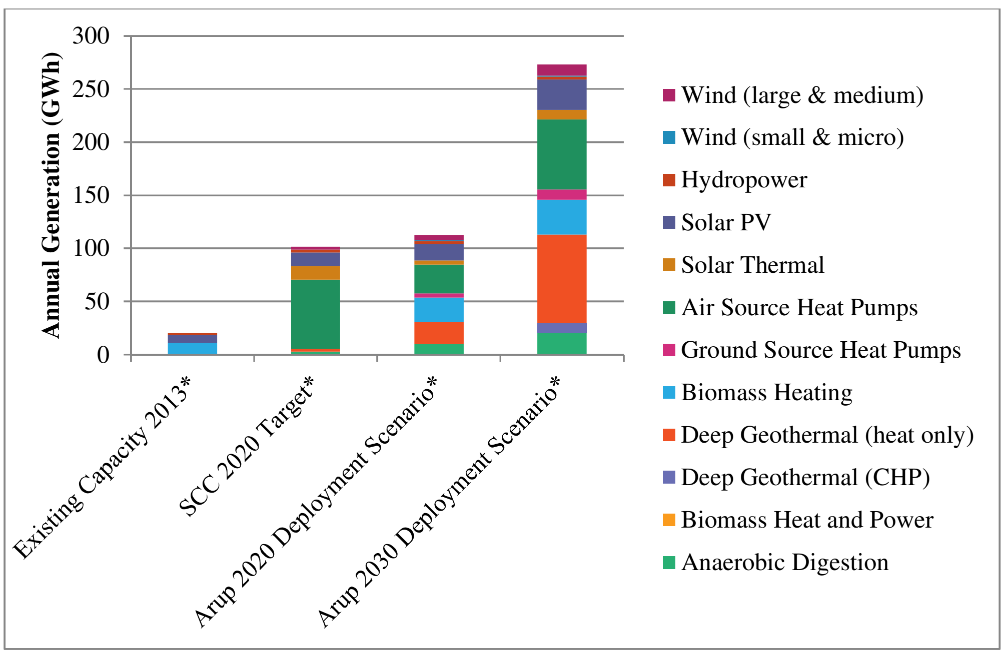

Figure 21 Total Estimated Resource Potential to 2020 and 2030

9.1 Contribution from Micro-Generation

With ongoing central government support from the Feed in Tariff and Renewable Heat Incentive schemes, micro-generation will make a significant contribution towards achieving SCC's target of 100GWh of annual generation by 2020. Micro-generation schemes are expected to represent over 85% of the installed capacity and over 65% of the annual generation in Sheffield by 2020.

Micro-generation schemes will make up the vast majority of the 6,750 sites as shown in Figure 22. Roughly half are expected to be solar PV installations with the other half being made up of a combination of renewable heat installations.

Given the number of installations required, SCC should consider how to further support and encourage householders and businesses to invest in micro-generation. SCC should lead by example by installing micro-generation on council owned properties wherever technically and commercially viable.

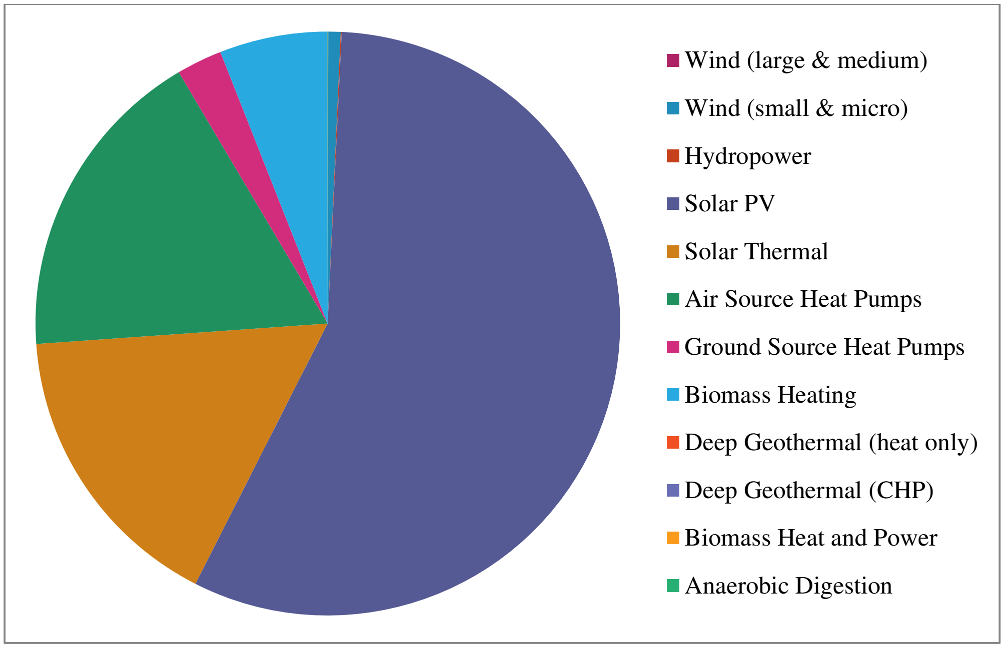

Figure 22 Numbers of installations per technology by 2020

9.2 Commercial and industrial scale developments

There are a number of potential opportunities for development of medium and large scale commercial renewable energy developments in Sheffield. The most significant opportunities are from wind energy, deep geothermal and anaerobic digestion. Developments will need to be sensitively sited to take into account key constraints including residential areas, green belt and the Peak District National Park. A number of potential sites are identified in Appendix A.

SCC should consider how to further support and encourage investment in specific technologies and identify key sites which could be promoted for renewable energy development.

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Appendix A

Potential Sites

Contents

A1 Wind Energy Sites

The following key constraints were used in GIS mapping software to identify potential medium and large scale wind energy sites:

- 400m buffer zone from residential properties.
- 1.5km buffer zone from the Peak District National Park.
- Not within green belt, sites of special scientific interest (SSSI) or Common land
- Buffer around major roads according to the turbine's fall over distance
- Sites sheltered by a large feature upwind were discounted
- 30km buffer zone from Civil Aviation Authority aerodromes
- No wind turbine blades over sailing public rights of way

By applying these buffers and reviewing the available remaining land in Sheffield, seven potential sites for medium and large scale wind energy developments have been identified as listed in the table below.

IT Power Ref	Location & Grid Reference	NOABL Wind speed @ 45m (m/s)	Greenbelt?	2006 Potential (MW)	Revised potential (MW)	Change since 2006	Notes
W1	Chapeltown SK 36487 96466	5.9	Yes	6	2.5	Reduced potential	The site is the only large site which is in Green Belt and considered as suitable for development. The site is near to the M1 and has old mine working spoil heaps in the area. A geotechnical survey would be required to ascertain the stability of the site, as foundations for a turbine could be prohibitively expensive. Probably only suitable for a single large turbine. Just within the 30km buffer zone of Doncaster Sheffield Airport.
W3	Ecclesfield SK 36572 95213	5.8	No	6	5	Reduced potential	Some of the site to the east is green belt. Site is currently waste land. Just within the 30km buffer zone of Doncaster Sheffield Airport.
W4	Greenland SK 440425 89756	5.7	No	0	0.5	Newly available	The removal of Sheffield City Airport opens this site up for development. Just within the 30km buffer zone of Doncaster Sheffield Airport.
W5	Handsworth SK 41132 87338	6.0	Part of site is greenbelt	0	0.5	Newly available	The site straddles Sheffield City Boundary and Green Belt. The removal of Sheffield City Airport opens this site up for development. Just within the 30km buffer zone of Doncaster Sheffield Airport.
W11	Alman Well Hill SK 28202 96820	6.0	Yes	Not defined	0.5	No change	Very small site could consider a medium turbine but too close to residential area for a large single turbine.
W12	Concord Park SK 38024 92562	5.8	No	Not defined	0.5	No change	The site is in green belt, close to houses and suited to a small single turbine. Just within the 30km buffer zone of Doncaster Sheffield Airport.
n/a	Tinsley SK 40484 88482	6	Adjacent	0	2.5	Newly available	The former site of Sheffield City Airport. Adjacent to green belt land. Potentially suitable for a single large wind turbine installation. Just within the 30km buffer zone of Doncaster Sheffield Airport.

A2 Hydropower Sites

The following potential hydropower sites have been identified:

IT Power Ref	Location & Grid Reference	River / Stream	Head (m)	Flow (m^3/s)	2006 Potential (kW)	Revised potential (kW)	Change since 2006	Notes
1	Niagara Forge SK 32807 91532	Don	3.1	3.17	78	56	Reduced potential	A fish pass has been installed.
2	Carbrook / Brightside SK 38718 90175	Don	2.15	5.72	76	61	Reduced potential	Interest shown by several companies with local companies interested in purchasing power produced
4	Rivelin Valley SK 32302 88720	Rivelin	1.3	1.1	10	10	No change	
6	Attercliffe / Sandersons SK 37281 88924	Don	1.7	5.48	60	43	Reduced potential	Listed structure, discussions on going at EA on installation of a fish pass, likely to be installed in the near future.
7	Leverston Street / Burton SK 36727 88195	Don	1.2	5.48	43	26	Reduced potential	A fish pass is to be installed in the near future
8	Effingham Street / Walk Mill Weir SK 36230 88140	Don	1.3	5.44	46	30	Reduced potential	A fish pass has been installed, land owner has also previously expressed interest in 'green' issues.
9	Wicker St / Lady Bridge SK 35713 87834	Don	1.4	5.02	50	50	No change	
10	Ball St. SK 35046 88273	Don	1.5	3.97	0	28	Increased potential	Listed structure
12	Waterford Rd / Wards End SK 34254 89127	Don	2.1	3.35	0	38	Increased potential	

13	Union Carbide / Beeley Wood SK 31861 91972	Don	1.2	3.55	30	30	No change	
21	Damflask Dam SK 28573 90554	Loxley	25	0.56	50	50	No change	Has been identified by Yorkshire Water as a potential site.
20	Rivelin Dam SK 27642 86922	Rivelin	25	0.11	25	25	No change	
n/a	Jordan Dam SK 40400 92200	Don	3	5.96	n/a	80	Newly identified	Considerable development by Sheffield Renewables, including planning and some permissions granted. There are current discussions within EA on installing a fish pass. YW have applied to OFWAT to budget for a fish pass here.
n/a	Hillsborough SK 33271 89603	Loxley	2.1	0.761	n/a	14	Newly identified	Recommendation made to install a fish pass.
n/a	Low Matlock SK 30600 89400	Loxley	2.5	0.761	n/a	16	Newly identified	Listed structure, recommendation made to install a fish pass.

A3 Deep Geothermal Sites

Identifying available sites for deep geothermal energy generation was not possible within the scope of this study. However, the available sites are likely to mirror those available for wind energy generation due to the following recommended constraints:

- 200m buffer zone from residential properties.
- 1.5km buffer zone from the Peak District National Park.
- Not within green belt, sites of special scientific interest (SSSI) or Common land
- 30km buffer zone from Civil Aviation Authority aerodromes (drilling rig is over 50m high)
- 0.4 hectares (1 acre) of nearly level land available for the rig
- Good access to a trunk road
- Preferably brownfield sites
- No sub-structures (sewers, tunnels etc)
- Not on top of ground liable to subsidence
- Good access to grid and/or heat connections
- Good access to water supply and wastewater processing

A4 Anaerobic Digestion Sites

Identifying available sites for anaerobic digestion was not possible within the scope of this study. However, the available sites are likely to mirror those available for wind energy generation due to the following recommended constraints:

- 200m buffer zone from residential properties.
- 1.5km buffer zone from the Peak District National Park.
- Not within green belt, sites of special scientific interest (SSSI) or Common land
- 0.4 hectares (1 acre) of reasonably level land available
- Preferably brownfield sites
- Good access to a trunk road
- Good access to grid and heat connections

Appendix B

Growth Rate Assumptions

B1 Summary of Growth Rate Assumptions

The following growth rate assumptions were used in building up the 2020 and 2030 scenarios:

Technology	Primary Constraints	No of micro-generation installations	Assumed Growth Rate
Wind (large & medium)	Number of sites further than 400m from houses		20% of available sites developed by 2020 40% of available sites developed by 2030
Wind (small & micro)	Deployment rate	10/yr	10 sites developed per year
Hydropower	Number of suitable sites with a sufficient head drop		20% of available sites developed by 2020 40% of available sites developed by 2030
Solar PV	Deployment rate	500/yr	500 sites developed per year based on historical FiT installation data
Solar thermal	Deployment rate	250/yr	50% of Solar PV installation rate = 250/yr
ASHP	Deployment rate	285/yr	30% of homes suitable. Of those, assume 6% of boilers are replaced each year, 10% of those choose renewable heat, 70% of those choose ASHP
GSHP	Deployment rate	41/yr	30% of homes suitable. Of those, assume 6% of boilers are replaced each year, 10% of those choose renewable heat, 10% of those choose GSHP
Biomass	Deployment rate and available biomass resource within 30 mile radius	95/yr	30% of homes suitable. Of those, assume 6% of boilers are replaced each year, 10% of those choose renewable heat, 20% of those choose biomass Growth rate continues until biomass supply is exhausted (up a maximum of 2,200 homes)
Deep Geothermal (heat only)	Number of suitable sites, access to finance for risky projects		1 plant developed by 2020 4 plants developed by 2030
Deep Geothermal (CHP)	As above		No development by 2020 2 plants developed by 2030
Biomass Heat & Power	Available biomass resource		Assume no further development as biomass supply is already used
AD	Available feedstock		20% of available capacity developed by 2020 40% of available capacity developed by 2030

Appendix C

Delivery Mechanisms

Contents

C1 Main Types of Delivery Mechanism

Delivery models can be classified generally into three main types:

1. Type 1: Private Ownership
2. Type 2: Joint Ventures, partnerships and SPVs
3. Type 3: Municipal ownership

C1.1 Type 1 – Private Ownership

A fully private sector led model, reliant on commercial finance at commercial investment rates. Whilst private sector organisations may be able to deliver certain efficiencies in performance (as a result, for example, of incentives for private investors to ensure that the prices for their products and services are revised regularly, that they meet particular targets and that they achieve good value on supply contracts and sale contracts) it is important to consider full definitions of performance. The public sector may attach higher weighting to non-financial aspects of performance such as fuel security, carbon reduction and alleviation of fuel poverty amongst vulnerable groups, issues that may be of less importance to private sector organisations.

C1.2 Type 2 – Joint Venture (JV), Partnership & SPV

A shared ownership model, using a public-private partnership structure and a combination of public finance / grant funding and commercial finance. Under an SPV/JV model it is important to ensure that each stakeholder is aware of their responsibilities and roles associated with project development. Figure [X] below sets out a typical SPV model highlighting the various roles required to be assigned.

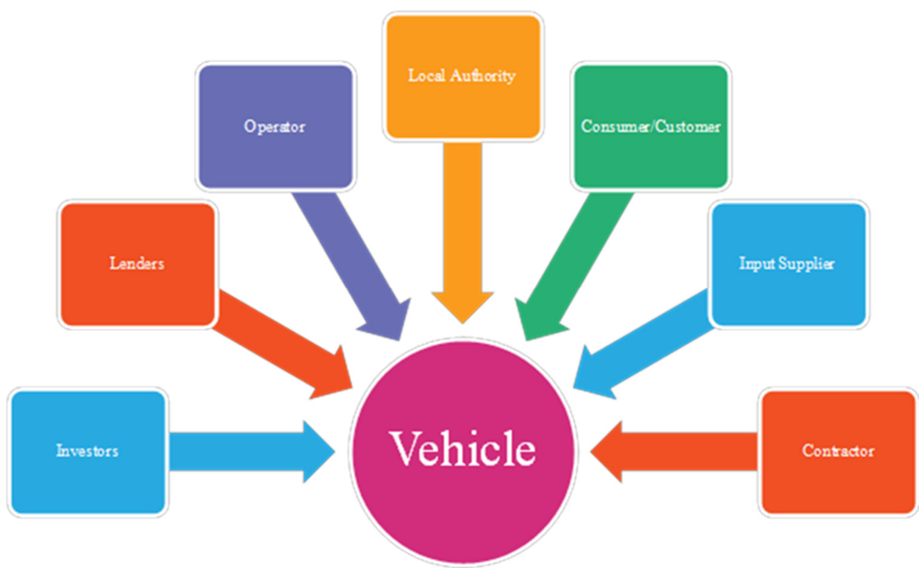

Figure 1 SPV Model

A joint venture (JV) and a Special Purpose Vehicle (SPV) describe the same type of organisation – a legal entity set up to implement a specific project or scheme. The reason for doing so is to share the project risks, especially start-up costs and operating losses that may prove to be uncertain. However, there is a high price to be paid to achieve risk-sharing: SPVs have high set-up and maintenance costs, and can be inflexible.

C1.3 Type 3 – Municipal Ownership

A fully public sector led delivery model using council funds and/or prudential borrowing to finance the project; Municipal energy schemes are characterised by their willingness to serve the public in a defined area. This is in contrast to privately developed energy projects in the UK which serve only a single or small set of customers, such as a factory, hospital or university campus. Aiming to meet the needs of the public may introduce additional complexity from having a large number of stakeholders.

The aims and objectives or municipally owned energy projects and initiatives will typically have different aims and drivers than a private sector based project. The result is that municipal owned projects struggle to meet the same outcomes as private sector led projects in terms of financial performance.

C1.4 Pros & Cons

The advantages and disadvantages of the three main delivery mechanisms are summarised below.

Type 1
PRIVATE OWNERSHIP

POTENTIAL ADVANTAGES

- Demonstrate best value through competitive bidding process
- Use existing commercial expertise/economies of scale
- Long-term contracts can allow stable funding
- No direct management responsibility/some risks transferred

POTENTIAL DISADVANTAGES

- Procurement costs may be high
- Risk of focus on generating profit at the expense of service
- Contracts may lack flexibility
- Loss of potential tax savings

Type 2
JOINT VENTURES, PARTNERSHIPS AND SPVs

POTENTIAL ADVANTAGES

- Scope for more responsive decision-making
- Opportunities to attract external investment
- Potential cost and business rates/tax advantages

POTENTIAL DISADVANTAGES

- May lose links with other council services
- Set-up costs may be high
- May lack a clear test to demonstrate best value
- Potential risk (eg, governance and trading) remain with the council
- Tax advantages may be withdrawn

Type 3
DIRECTLY MANAGED COUNCILS

POTENTIAL ADVANTAGES

- Flexible to service changes
- Opportunities for joint working across departments
- Use of prudential borrowing
- Strong elected member support and influence

POTENTIAL DISADVANTAGES

- Risk of competing political or budget priorities
- Potential restrictive council terms and central costs
- May lack a clear test to demonstrate best value

Figure 2 Advantages and disadvantages of the main types of delivery mechanisms

C2 Alternative Delivery Mechanisms

Alternative delivery mechanisms include:

1. Type 4: Social Enterprise
2. Type 5: Community Interest Companies
3. Type 6: Energy Service Companies
4. Type 7: Delivery by local authority
5. Type 8: Trusts

C2.1 Type 4 – Social Enterprise

Social Enterprises relates to businesses which trade within a market with a social purpose. Social Enterprises can take a number of different legal forms and may provide the Council with the opportunity to involve organisations which would not typically be interested in the development of energy projects.

C2.2 Type 5 – Community Interest Companies

A Community Interest Company (CIC) is a limited liability company designed for social enterprises that want to use their profits and assets for the public good. A CIC has a specific aim of providing a benefit to a community and must use its income, assets and projects for the community it is formed to serve. As such a CIC does not have the primary purpose of benefiting its shareholders, directors of employees. A CIC must continue to satisfy a community interest test.

C2.3 Type 6 – Energy Service Companies

The term 'Energy Service Company' or ESCO is a generic term for a SPV set up to deliver energy efficiency, energy savings or energy infrastructure.
For renewable energy projects, typically the ESCO will build, own and operate a renewable installation and sells the generated energy to a consumer. An ESCO does not need to be a company formed and incorporated under the Companies Act.

C2.4 Type 7 – Delivery by local authority

The local authority would adopt the roles of sponsor, funder, owner and operator where appropriate. It is very rare that a local authority will be able to carry out all project functions itself and as such this model focuses on achieving minimal input from other organisations. This model is likely to only be relevant where projects are low cost, low risk and short-term.

C2.5 Type 8 – Trusts

A trust may be set-up in order to deliver projects where the purpose of the trust can be regarded as charitable and for the benefit of the public.

C3 Roles & Responsibilities

There are a range of actions and deliverables that need to be completed (the responsibilities) by a range of different organisations and stakeholders (roles) in order to deliver the project successfully.

Any stakeholder could potentially have more than one role and responsibility as part of the project and it is important that roles and responsibilities are defined clearly, so that the associated risks of all stakeholders involved in the project are understood. Figure 3 below shows the main responsibilities which need to be understood and assigned to the relevant parties during project development.

Figure 3 Typical responsibilities for energy project development

The typical roles associated with energy project development are:

- Regulator
- Governance
- Project Sponsor
- Asset Owner
- Operator
- Supply Chain Manager
- Retailer
- Developer

The extent of the responsibility associated with each role will vary on a project by project basis. In practice these roles are usually assumed by a small number of parties depending upon project scale. For example the development of a small scale renewable installation is likely to involve a local authority, a specialist operator and the project developer.

C3.1 Regulator

Elements of some energy projects, such as those involving the generation of electricity, are regulated and some are not. The level of regulation already in place will vary significant depending on project type and therefore it is important to ensure that the regulatory requirements of any project are fully understood.

The role of a regulator is particularly important where a project involves stakeholders who may be considered less knowledgeable or experienced with regards to the project than other stakeholders. For example where a private organisation is engaged to supply a product or service to social housing tenants on behalf of a local authority it will be important to ensure that all business is conducted fairly and transparently.

Typically where a regulatory body or organisation is in place the functions performed will include:

- Setting operating standards for developers and operators
- Setting commercial terms for operators
- Establishing criteria for consumer protection
- Establishing planning constraints
- Monitoring performance of operators

Where an established regulator is not in place it is considered good practice for project stakeholders to agree to a pseudo-regulatory regime, agreed during project development. This will help to ensure the standards and terms under which the project are developed and operated are upheld in the long term.

C3.2 Governance

Governance is distinguished from regulation in that it concerns business practices rather than relationships with consumers. For example, where a citywide delivery vehicle might use public funds to invest in assets and use its own initiative to create a better defined regulatory environment, it must ensure that there is a proper system of public accountability for its actions. This Governance function might include:

- Intervening where necessary, such as in service disputes or contractual disagreements
- Accountability and reporting to stakeholders
- High level supply chain management

C3.3 Sponsor & Funder

The role of sponsor will vary significantly depending upon the project type being undertaken and the model by which the project is intended to be delivered. The role of sponsor can be undertaken at several levels including:

- Initiatives that are intended to influence energy demand, consumption and provision.
- Promotion of a wider energy scheme through linking served sites.

- Facilitating the provision of individual renewable energy schemes for specific developments.

For individual development projects, sponsorship includes all the activities involved in project creation and delivery, short of investment in the finished scheme. That is, sponsors, like developers, have only a time-limited interest in the energy schemes they set up. The activities include:

- Undertaking investment appraisals
- Undertaking business portfolio management
- Securing funds
- Defining and guaranteeing the scale and timing of demand for services
- Defining the physical nature of the project
- Controlling development
- Procuring developers, investors and operators

It might be considered that Funder is a separate role to be assigned. Several parties may contribute to the initial financing of an energy project, including Developers, Operators, Asset Owners, and project Sponsors; these parties may inject their own funds (equity), borrow or have access to grants.

The precise combination of equity, debt and grant funding will depend on the characteristics and aims of each project. In the long run, revenues from customers enable initial investments to be remunerated and further investment to be made out of cash flow. Guarantees or the underwriting of demand and long term contracts may therefore be considered a form of funding. The project Sponsor has the responsibility to ensure that adequate funding is available. Accordingly, it may not be appropriate to separate out funding as a separate role to be assigned.

C3.4 Ownership

The asset owners have an interest in securing the long term returns generated by energy projects. Depending upon the project structure they may be specialist asset management companies such as pension funds or infrastructure funds, and are often the parent company of an Operator. Projects comprising of multiple assets (e.g. renewable energy installations on a school or development of a CHP and district heating scheme) may have multiple asset owners due to the different characteristics of the assets (complexity, longevity, maintenance regime). The functions of asset owner include:

- Arranging finance and providing financial guarantees
- Investing in replacement and enhancement
- Contracting with installers, operators and specialist services companies

C3.5 Operation

The requirement for an operator is particularly relevant to projects which include complex assets such as electricity or heat generation plant or where projects require significant levels of intervention. In the UK, operators of energy projects tend to focus on technical and operational aspects, handing off customer relationships and other management functions to a separate organisation (e.g.

landlords or specialist service companies). The full range of functions associated with an operator can include:

- Operation and maintenance of assets and associated works.
- Responsibility for plant availability
- Management of assets and associated services
- Procurement of products and services required in operation and maintenance activities
- Providing insurances and guarantees of supply quality
- Monitoring performance
- Customer services

C3.6 Supply Chain Management

Supply chain management may be separated from operation as it requires specialist brokering skills. The extent of the role will vary considerably from project to project, with large scale, complex projects potentially requiring the engagement of specialist supply chain managers while the role on small scale, short term projects could be adopted by the developer or other party.

C3.7 Retailing

Where an energy project involves the sale of a product or service to a consumer the role of a retailer may be defined. A specialist service provider may be engaged to undertake services such as metering and billing, pricing and customer services where appropriate.

C3.8 Developer

Project developers are generally not interested in participating in energy projects as either operators or asset owners. If they take a role as project sponsors, they typically prefer an early exit. Their essential functions are:

- Providing the development opportunity for an energy project (e.g. clarifying and validating demand guarantees or identification of opportunities for energy efficiency schemes.)
- Funding through contribution in kind(e.g. avoided cost contributions)
- Managing programme risk

Developers typically are focussed on the differences in investment cost of an energy project compared to conventional solutions.

C4 Transactions

The delivery model options suitable for each project will depend upon the range of transactions associated with the project and its scale type. Figure 4 below provides an example of the transactions associated with a large scale energy infrastructure project delivered through an SPV model.

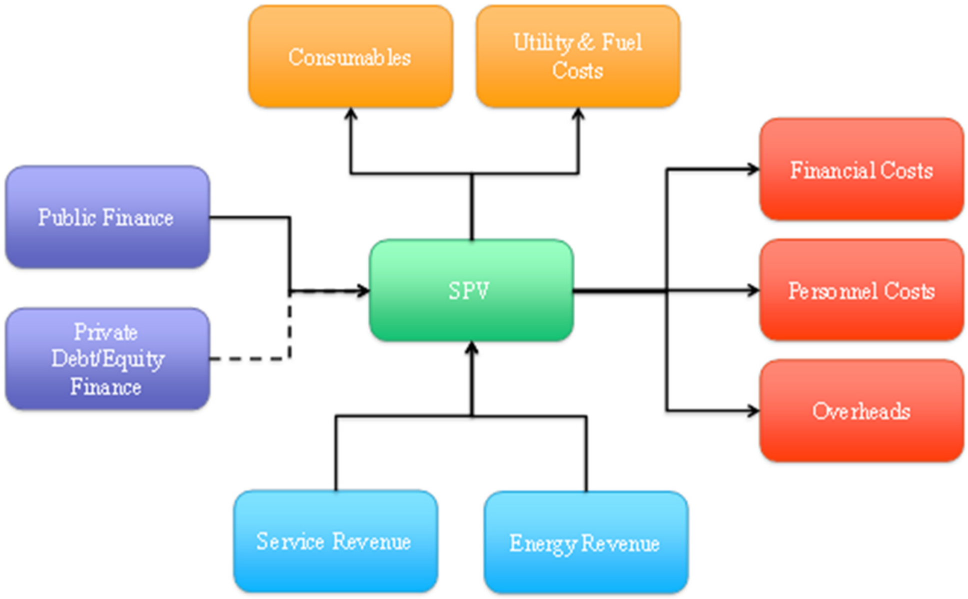

Figure 4 Overview of the transactions associated with a larger scale energy infrastructure project delivered through an SPV model

Appendix D

Business Rates Retention

Contents

D1 Business Rates Retention

D1.1 Introduction

A business rates retention scheme was introduced from April 2013. Local Councils are now able to keep a proportion of the business rates revenue as well as growth on the revenue that is generated in their area. The scheme provides a financial incentive for councils to promote economic growth.

The Department of Communities and Local Government published a Plain English Guide which explains the scheme in more detail (DCLG, Dec 2011).

D1.2 How does this apply to renewable energy installations?

The scheme allows local authorities to keep 100% of the business rates relating to new renewable energy projects within their area (DCLG, May 2012). Furthermore, additional business rates income from such renewable energy projects will be disregarded from calculations of the central/local share, levy, and re-set of tariff and top-up amounts.

The following technologies are eligible for the scheme (DCLG, May 2012):

- onshore wind power
- offshore wind power
- hydroelectric power
- biomass
- biomass conversion
- energy from waste combustion
- anaerobic digestions, landfill and sewage gas
- advanced thermal conversion technologies – gasification and pyrolysis
- geothermal heat and power
- photo-voltaics

D1.3 References

DCLG. (Dec 2011). *Local Government Resource Review: Proposals for Business Rates Retention Consultation - Government Response.*

DCLG. (May 2012). *Business rates retention scheme: Renewable Energy Projects - A Statement of Intent.* Retrieved January 13, 2014, from https://www.gov.uk/government/publications/business-rates-retention-scheme-renewable-energy-projects-statement

Appendix E

Case Studies

Contents

E1 Jordan Dam Hydropower

E1.1 Introduction

Between 2009 and 2013, Sheffield Renewables investigated the feasibility of an 80 kW hydropower scheme on the River Don near Meadowhall. This project would have been the largest community hydro scheme in England. Having decided to go ahead with the project, they raised finance through a community share offer and started a procurement process. In March 2013 the project ran into difficulties and Sheffield Renewables decided to invest in other schemes instead. This case study tells to story of the route to development taken by Sheffield Renewables; the key constraints and barriers encountered along the way; and outlines some of the project finances.

The organisation

Sheffield Renewables is a social enterprise that operates as a volunteer led community organisation, with the aim of developing renewable energy schemes in Sheffield. Surplus earnings are re-invested to develop new projects as well as to benefit local disadvantaged people through the community benefit fund. The organization is legally incorporated as an Industrial and Provident Society for the Benefit of the Community (IPS BenCom). This status enables the organisation to finance projects by selling community shares, primarily to people and businesses within Sheffield.

Project overview

Located at Jordan Dam, next to Blackburn Meadows Wastewater Treatment Works, the proposed scheme would have used an 80 kW Archimedes screw turbine to produce 310 MWh a year. Yorkshire Water (YW) agreed to purchase the electricity generated by the scheme, which would be used by the sewage works. Sheffield Renewables developed the scheme to an investment ready stage, but due to several factors, the scheme did not go ahead.

Figure 1 Artists impression of the proposed Jordan Dam hydropower scheme

E1.2 Development timeline

The project took on 5 distinct phases outlined below.

Phase 1- Consultation and initial feasibility

A report was done for Sheffield Renewables detailing the opportunities for setting up small hydropower schemes. This was followed by an initial feasibility study that assessed the flow within the River Don and identified suitable weirs. A shortlist of weirs was modelled. This took into consideration flow rate and the height of weirs to produce an approximation of the amount of power that could be produced from schemes at these locations. From this assessment, Jordan Dam was identified as the most suitable site due to the space available on/next to the weir and because it had the highest flow rate and potential power output.

Phase 2 – Detailed feasibility and design work

The second phase of the project involved detailed feasibility work and a full design of the proposed hydropower plant. A detailed feasibility study was carried out by Derwent Hydro in April 2010. This included design, costing and environmental appraisal of the proposed scheme.

The planning application for Jordan Dam was submitted in February 2011 and took 3 months to be processed. Permission was granted and remained valid for 3 years until May 2014. Key stakeholders engaged in the process included the Environment Agency (EA), Canal & River Trust (CRT) and Yorkshire Water (as the 'neighbour' and land owner).

Key documents required in order to apply for planning were;

- Ground gas risk assessment
- Ecological assessment
- Design and access statement
- Flood risk assessment
- Contaminated land study
- Site investigation report

The Abstraction Licence was granted in May 2012 and is valid until May 2015. The licence would then be valid until March 2029 if the scheme had proceeded. The conditions of the Abstraction Licence state that 'No abstraction for the purposes of hydroelectric generation shall take place until the licence holder has installed a fish and eel pass which the Agency has approved in writing'. An initial fish pass design was created for the Abstraction Licence application but this was not formally approved by the Fish Pass Panel.

Phase 3 – Share Offer

A share offer, run mainly by volunteers, raised a portion of the capital required for the scheme, £217,000 in total. The community share offer was publicised through attending public events and holding consultation evenings with potential investors, as well as engaging with 'green' media and local organisations. The share offer ran for 3 months, with the majority of shares bought towards the end of the share offer.

Loans were used to make up the shortfall in finance, the terms for these had been agreed prior to the launch of the share offer.

Phase 4 – Tender process

A project manager was appointed to manage the tender process, who put together the instructions for tendering. A Design and Build and Specialist Plus approach with an NEC Engineering and Construction Form of Contract were used so that all design liabilities were placed on the contractor, giving greater cost certainty as well as mitigating risk to Sheffield Renewables. The tenders came back at considerably higher prices than initially anticipated, at £850,000 to £1.3 Million. Estimates had been made based on costs from other schemes and advice from consultants at between £560,000 and £730,000. Several factors caused prices to be considerably higher than initial estimates; the discovery of a sewer outflow during pre-tender site investigations and site complications, including the removal of contaminated waste, increased the cost of the scheme as well as additional fish pass requirements from the EA. During the tender stage an alternative on-weir design was proposed that could have potentially reduced costs and simplified construction, but due to funding and time constraints it was not possible to pursue this option.

Phase 5 – Implementation

The construction phase was predicted to run for between 4 and 6 months. There were risks associated with the construction phase; the main risk was the potential for causing instability in the sewer that runs under the construction site. Secondary risks included the potential for an uncontrolled breach of the riverbank due to high river levels and the limited access to the site for construction vehicles and personnel.

Operational Lifetime

The scheme was predicted to be fully operational for a minimum of 40 years, with the generator needing replacement after around 20 years at a cost of around £10,000. FiT payments would cease after 20 years but revenue from electricity sales would have continued.

E1.3 Major constraints and barriers

Fish pass

The uncertainties associated with the design, location and number of fish passes required was a considerable factor to the project not going ahead. It became clear during the tender process that there was a risk that the proposed fish pass would not meet the requirements of the Water Framework Directive and if not, a second fish pass would be required, adding considerable cost (around £200k-£300k).

The EA is focused on maximising the migration potential of fish at every obstruction on the river network and under the Water Framework Directive the landowners are responsible for fish passes. The burden of paying for a fish pass at Jordan Dam now lies with YW, EA and CRT. A more effective way to deal with this issue may have been for all stakeholders to be drawn into a public partnership, with the responsibility for providing fish and eel passes being apportioned in accordance with the benefit each stakeholder receives.

Organisational constraints

As a voluntary organisation, Sheffield Renewables encountered additional constraints when developing the project. Volunteers had to carry out work in their own time and often had other work commitment as well. The commitment volunteers were able to give varied considerably. This became problematic for the external organisations Sheffield Renewables dealt with, when key volunteers stepped down and others picked up the work. Sheffield Renewables also received support from other voluntary organisations. This work was invaluable, but it would have been simpler and more effective if Sheffield Renewables had the experience to do the work themselves.

Risk management

At every stage of the project development Sheffield Renewables took a comprehensive and proactive approach to risk management due to their commitment to their shareholders. As a consequence of this the overall price of the project was inflated. Had Sheffield Renewables been prepared to take on more of the risk, in such areas as performance guarantees for the hydro plant and additional fish pass requirements, the project may have gone ahead, but at risk of diminished financial returns.

Buried infrastructure

The late discovery of the sewer under the site, led to significant extra cost being associated with the construction of the scheme. If it had been discovered during the detailed feasibility study or if a topological survey was carried out earlier in the design stage, it may have been possible to alter the design to avoid building over the sewer. More readily available site maps would also have helped - it took over 6 months to obtain these.

E1.4 Project finances

Capital costs

	Cost, £	Notes
Fixed Price Contract	£0.85m – £1.3m	Based on tender prices
Project Manager	£35,000	1 year at £30k p.a. plus ON costs (YW want someone on site full time)
Third party fees	Confidential	Fees to YW, CRT and SCC

Funding

	Amount, £	Notes
Share's	£217,000	▪ 3% Interest after operating for 2 years (i.e. from year 3 on) ▪ Withdrawal after operating for 3 yrs (i.e. from year 4 on) ▪ Complete withdrawal of capital over 20 years ▪ Interest and withdrawal not guaranteed
Loans	To cover shortfall	2 separate loans with terms of between 18 -20 years.

Income

	Amount	Notes
Average annual power output	310 MWh	Feasibility Study, this is a conservative estimate
Feed in tariff unit price	19.7 p/KWh linked to RPI	Generation FIT from Oct 2012
Electricity sale unit price	At a competitive market rate	YW proposed to purchase all the electricity generated, to be used at the treatment works next to the site.

Operational expenditure

	Amount	Notes
Maintenance (Routine)	£7500/year	Daily site visits required to clear screen and refill lubricant every 6 weeks. An annual inspection required by a qualified hydro engineer.
Insurance	£2300/year	
Small business Rate	20%	2011 rate
Annual Investment Allowance	£25,000	▪ AIA rate from April 2012 ▪ We are eligible for AIA in year 1
Writing down allowance [Long life Plant and Machinery]	8 %	▪Special Pool rate from 2012

		▪Assume can claim capital allowances for entire capital spend as a long life plant and machinery asset

E1.5 Summary

The project became infeasible due to several key issues:

- the late discovery of buried infrastructure
- the potential additional fish pass requirements
- risk averse approach by Sheffield Renewables

The scheme would have been financially viable if the fish pass had been funded by other means and there are current discussions within the EA to put a fish pass in at the site.

This does not mean a hydro scheme would not be feasible at this site, but the path taken by Sheffield Renewables rendered the project no longer viable. Other hydropower schemes have run into similar difficulties, especially around fish issues. Some have been able to overcome these, others haven't.

Lessons learnt

- A larger contingency should have been budgeted. The 10% contingency fund did not adequately cover the risks. A 15% fund would have covered the higher than expected tender prices. A 30% fund would have covered the cost of additional fish pass requirements.
- With a large proportion of the early funding coming from grant bodies, work could only be done when this funding was available and not necessarily when it should have been done, or in the right order.
- A topographical survey should have been carried out with the detailed feasibility study.
- Early discussion and negotiation with the EA particularly around fish pass approval could have reduced the impact the fish pass design had on the project failing to go ahead.
- These risks were identified on Sheffield Renewables' risk register, some of these however were not apportioned a high enough risk rating.
- Some consultants may not have recognised the specific guidance needed by Sheffield Renewables and therefore may not have given comprehensive and timely advice.

E2 Lower Don Valley Heat Network

E2.1 Introduction

E.ON has announced the details of their Lower Don Valley Heat Network which will supply up to 25 MWth of heat to customers on the East of Sheffield from the Biomass CHP plant at Blackburn Meadows. The business case for the network was supported by key anchor customers including Sheffield Forgemasters and Sheffield International Venues (SIV) and E.ON is now seeking interested parties in the Don Valley region.

The organisation

E.ON is one of the UK's big six energy companies - generating electricity, and retailing power and gas. Their strategic aim is to deliver cleaner and better energy by offering innovative energy services and technologies tailored to meet their customers' needs. The Blackburn Meadows site has had an energy generation presence in Sheffield since 1921 with coal fired power stations operating until 1980. In 2008, planning permission was granted to E.ON for a new Biomass heat and power plant on the site of the former coal power plant adjacent to the M1.

Project overview

The heat network will be built in phases, with the first two phases (as indicated by the pink and blue lines in Figure 2 below) reaching East End Park through the main 'spine' of the network. It consists of 2 x 350mm super-insulated steel pipes with integrated leak detection alarm system.

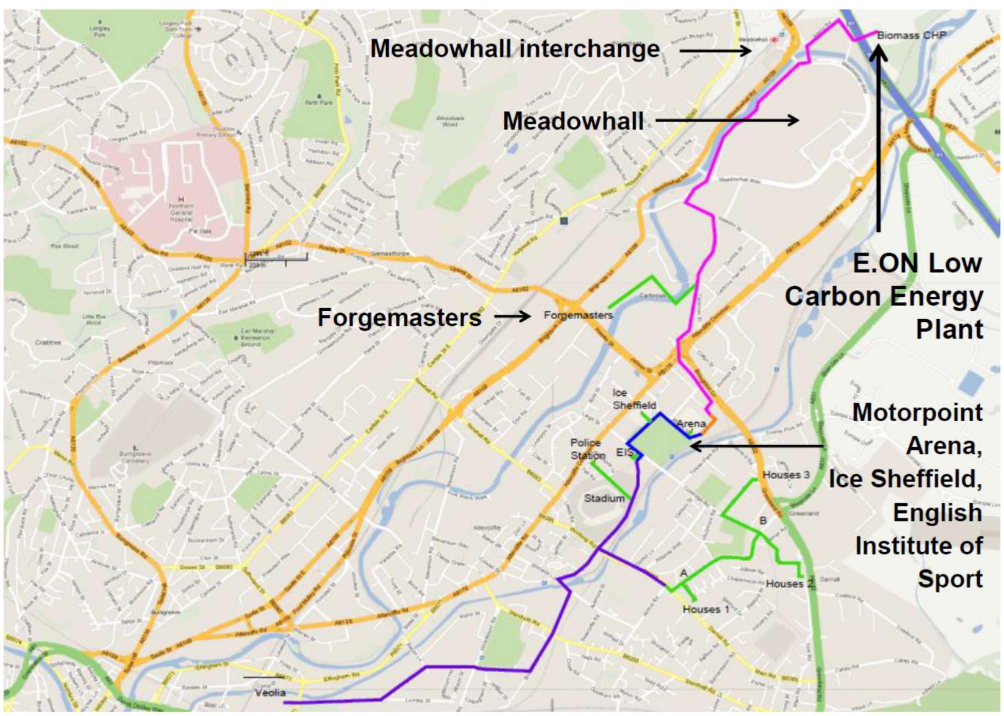

Figure 2 Lower Don Valley Heat Network

E2.2 Development timeline

Key stages in the development timeline were as follows:

- 2011 – Initial feasibility study
- 2013 – Detailed feasibility and design
- 2008 – Planning permission granted for a low carbon plant with conditions to fully evaluate the potential for an associated heat network
- 2008 – Site preparation began with the demolition of the famous cooling towers beside the M1
- 2010 – The M1 Gateway art project began to study ideas
- 2011 – Ground works commenced on the new biomass CHP plant
- 2012 – Construction was well underway
- 2014 – The plant will produce power
- 2015 The plant will produce heat and distribute it through the Lower Don Valley Heat Network

The plant is designed to operate for at least 25 years. E.ON has a 25 year contract in place with wood recycling company J Plevin and Sons.

E2.3 Key enablers

Retrofit projects of this nature require courage and commitment and a true collaborative approach from many key stakeholders. To enable investment in such infrastructure, anchor customers are required to commit and support the project at all levels. Similarly, the role of the Local Authority is paramount to the success of such a project as it not only supports many local policy and strategic aspirations but also ensures a joined up approach to delivery to align with other major infrastructure projects. Other notable enablers include Meadowhall in their co-operation and support on the route of the network and Veolia Environmental in assisting with the development and future connectivity of the two projects

Support from Sheffield City Council

The Local Authority has supported the project on many levels and had an overarching view in ensuring all touch points with the Council are aligned and informed – from highways, planning, housing, sustainability, strategy and policy, regeneration and inward investment. The Local Authority is also a trusted brand that has successfully assisted in the promotion and enablement for potential customers to the scheme.

Infrastructure and industry

As was identified in the initial feasibility studies, a number of opportunities for district heating in Sheffield were identified. The Lower Don Valley was identified as the highest probability and priority given the investment in the Biomass Power Station CHP from as heat source perspective. This was matched with substantial heat demand in what is one of the highest density areas for industry, commerce and housing – The Lower Don Valley.

Anchor customers

- Sheffield Forgemasters
- SIV assets in the Lower Don Valley – English Institute of Sport, Motorpoint Arena and ICE Sheffield.
- Veolia Environmental Services has also signed an options agreement that could see the two heat networks join in the future.

E2.4 Key constraints

Customer interest and security is critical to demonstrating the viability and commitment to invest in the infrastructure. Equally, the local planning policies and strategies that support and promote connection to the infrastructure are essential for new build projects.

Retrofitting major infrastructure in a dense urban environment is a challenge. Some of the key challenges in defining the route were:

- M1 Viaduct and existing major utilities within the locale of the Power Station
- River Don
- Canal network
- Tram
- Rail
- Highways PFI replacement programme
- Tinsley Link Road
- Bus Rapid Transit and junction upgrade programme
- Traffic Management – major arterial routes in and out of the city
- Meadowhall – major venue and traffic management

E2.5 Project finances

Capital investment

	Cost, £	Notes
Biomass CHP plant	£120m	
Lower Don Valley Heat Network	£20m	Includes the heat network of approx. 10km, plant room modifications and the dedicated energy centre on site at the Power Station to accommodate all pressure sets, water treatment, control systems and pumps.

Annual investment

	Amount, £	Notes
Community Benefit Fund	£25,000	
Business Rates	To be confirmed	
Total Annual Operating Costs	Commercially sensitive	

Income

	Amount	Notes
Average annual heat sales	Commercially sensitive	
Heat sale unit price	At a competitive market rate	

E2.6 Benefits to the local economy

Employment

The operation of the plant will create direct employment of around 30 local people. Indirect jobs have been created through the construction and supply chain throughout Sheffield and the surrounding area.

Business rates

Sheffield City Council will receive business rates from E.ON which can be retained by the Council to invest in local services.

Improved resilience

Opportunities exist to expand the network to include additional heat sources, with waste heat from Forgemasters for example. By building the network, an open market opportunity is created for other parties to supply or take heat.

E.ON and Veolia, a key stakeholder in the development of this project, have an outline agreement to potentially connect the Lower Don Valley Network to the existing network in the City Centre – to allow further expansion and combined network resilience.

Reducing energy prices

The E.ON Community Energy customer price promise, means those connecting to the heat network will benefit from reduced heat costs compared to their existing supply.

Numerous options for additional customer connections are currently being evaluated. These include proposals for further expansion of the network within the Lower Don Valley.

E2.7 Wider benefits

The plant will have wider environmental and energy security benefits particularly in terms of reducing global climate change impacts:

- 29MWe power generated, enough for 40,000 homes and 25MWth heat
- Displaces 80,000 tonnes of CO_2 – Equivalent to 20,000 cars. The estimated carbon content of the heat from the network has been calculated to be 0.076Kg/kWh of CO_2. This accounts for the electricity needed for the pumping of the water.
- Fuelled by 250,000 tonnes of otherwise wasted wood, diverted from land-fill

E3 Heating Social Housing

E3.1 Introduction

Sheffield City Council's Housing Service is responsible for managing 42,000 council houses in Sheffield. This is approximately 18% of the total housing stock in the city. As part of the Decent Homes programme which has been running since the early 2000s, the council has funding to improve the internal conditions of the council housing stock. This includes a programme to replace and/or upgrade 10,000 central heating systems in the next four years (2014-2018).

The organisation

Sheffield City Council's new Council Housing Service aim's to deliver efficient, high quality housing services, provide decent homes, build thriving communities and improve the lives and prospects of their customers. For 9 years, council homes in Sheffield were managed by the Arm's Length Management Organisation (ALMO) Sheffield Homes. In 2012 tenants voted to return council housing services in the city to the direct control of Sheffield City Council. On 1st April 2013 over 1000 Sheffield Homes staff transferred into the Council and are now working with customers to plan the next phase in the future of Sheffield's homes and estates.

Project overview

The government believes that all social housing should meet a minimum standard of decency. Social housing should, amongst other things, have reasonably modern boilers and be reasonably insulated. To help local councils with the worst housing, the government provided grants through the Decent Homes programme.

In 2008, Sheffield Homes instigated a programme to update boilers and heating systems throughout the council housing stock. This is starting to reap benefits in terms of reduced breakdown frequency and annual maintenance costs.

Whilst many council houses in Sheffield have already been upgraded, the council has a continuing programme of boiler replacements. Boilers are replaced once they become obsolete (for example when replacement parts are no longer available) and/or approximately every 15 years.

Business as usual is for the boilers to be replaced with modern, high efficiency gas combination boilers. This case study examines the possibility of replacing boilers with air source heat pumps (ASHP) instead. Other renewable heating solutions were discounted for the following reasons:

- Solar thermal hot water - available resource is not able to provide space heating requirements and is therefore not a suitable alternative to replacement gas boiler systems.
- Ground source heat pumps – more likely to be suited to community heating schemes serving multiple properties due to the scale of investment needed.
- Biomass boilers – more likely to be suited to community heating schemes due to more onerous space and maintenance requirements.

- Fuel cells – now commercially available but system reliability is very poor when compared with other technologies at this stage. May be worthy of further investigation in future years when the technology is more mature.
- Deep geothermal – only suitable for district or community heating.

ASHPs provide the most similar heating system to a conventional gas boiler system and would fit most easily within the council's existing boiler/heating system replacement programme.

E3.2 Development timeline

Key dates in the council boiler replacement programme are as follows:

- 2008 – Sheffield Homes heating strategy introduced. Rolling programme to replace boilers once they become obsolete.
- April 2013 – Sheffield Homes services returned to the council's control
- April 2014 – Domestic Renewable Heat Incentive (RHI) introduced to support investment in renewable heat systems. This includes support for air source heat pumps.
- 2013-14 – Procurement of boiler supply contracts.
- Financial year 2014/15 – the council Housing Service plan to replace 2,500 whole heating systems including boilers with high efficiency gas combination boilers. A further 200 boiler only replacements are anticipated.
- Future years – The heating system replacement programme is likely to include a further 7,500 full heating system replacements in the following three years. After that, the backlog of heating system upgrades will have mostly been cleared and the programme will revert to a higher proportion of boiler only replacements.

Domestic boilers are expected to have a 15 year lifespan. The rest of the heating system including radiators, pipes, valves and fittings are expected to have a 30 year lifespan.

E3.3 Experience from previous ASHP schemes

Experience was sought from other social housing providers and ASHP suppliers who have installed ASHPs in social housing. Experience was rather mixed, although a common theme was to highlight the importance of providing information and support to tenants on the change from more conventional heating systems and how best to operate the system. This is backed up with experience from the Energy Saving Trust (EST) which has conducted field trials of heat pumps in the UK[1]. EST observed that "Installer practise and customer behaviour can still impact performance."

Berneslai Homes, Barnsley

Berneslai Homes is replacing 10,000 heating systems over the next four years. Following a successful pilot programme (based on 10 properties), ASHPs are now the favoured solution and the heating replacement programme will be predominantly based on ASHP systems by 2015. The key driver for this is the income from RHI.

Most of the installation work is varied out by their in-house teams of installation contractors using Mitsubishi EcoDan heat pumps. The installations offer substantial reduction in heating costs for homes which have switched from solid fuel (mainly coal) heating. For those properties which are converted from gas boilers the experience has generally been of improved comfort levels and slight reductions in heating costs for tenants.

Salix Homes, Salford

Salix Homes has decided not to progress with ASHP installations due to the perceived running cost premium and despite the income from RHI. They have some examples of ASHPs which have been removed after less than two years due to poor performance. This is thought to be in part due to poor system design and installation – their experience being that ASHPs are not well understood by domestic scale installers.

Harrogate Borough Council

Harrogate Borough Council (HBC) has adopted ASHPs as the preferred heating technology for all off-grid properties. Gas boilers continue to be used for grid-connected properties. This is due to the cheaper capital cost of installation and the marginal savings for consumers.

HBC installed over 200 heat pump systems so far with a programme to increase this by 69 properties next year. Experience so far has suggested that education of tenants is one of the key success factors. Good communication and long term relationships between council, tenant and contractor has been essential. Their approach has included:

- Educational DVDs from the equipment supplier;
- Information leaflets;
- One-to-one meetings in the property before and after the installation; and
- A dedicated team providing support to tenants in the first year following installation.

E3.4 Key enablers

There are several key enablers when considering an investment by Sheffield City Council in ASHPs for council housing:

Buying power

Whilst most home owners would buy only one system at a time, Sheffield City Council can maximise its buying power with a contract to supply ASHPs to multiple council houses. This should reduce the overall cost per unit.

Access to prudential borrowing

As a local authority, the council can access public borrowing at more favourable rates than commercial investors. This means that investments at lower rates of return could still prove to be economically viable compared with commercial investments.

Renewable Heat Incentive (RHI)

The RHI is specifically designed to make access to renewable heat more affordable. Rather than expecting property owners to install additional technology, the domestic RHI is a boiler replacement scheme. Its aim is to enable renewable heating systems to compete on a level playing field with fossil fuel ones. The payments, which are made over seven years, compensate the owner for the price difference between the two, including the cost of borrowing money to pay for installation.

In addition to any saving made by the owner/tenant on energy bills, a generation tariff is paid for every unit of heat generated. The domestic tariff for ASHPs is currently set at 7.3 pence per kWh of heat generated.

The tariff level is set at a level to particularly help people who do not have access to mains gas to shift from oil, LPG or electric heating to renewables. It is less likely to be cost effective for homes on mains gas supply.

Lower maintenance costs

ASHP maintenance costs are likely to be lower than the equivalent cost of gas boiler maintenance. Typical annual checks would involve checking the electrics, heating valves, then removing the covers and brushing the fans. It is expected that a qualified engineer would be able to carry out 10 of these checks per day compared with five gas safety checks. An experienced MCS accredited installer has indicated that potential cost savings are likely to be in the region of 25 - 35%.

New building programme

The council has made a commitment to build 600 new council houses. ASHPs and other renewable or low carbon heating systems should be considered as part of these developments.

Combining an ASHP installation with other building work or new build developments can reduce the cost of installing the system. ASHPs can perform better with underfloor heating systems or warm air heating than with radiator-based systems because of the lower water temperatures required.

Re-roofing and solar PV

The council is investigating the possibility of investing in rooftop solar PV on council houses in conjunction with a major re-roofing programme. Where PV is installed, the energy cost saving associated with ASHP installation could be significantly enhanced.

E3.5 Key constraints

Similarly, there are several key constraints when considering an investment by SCC in ASHPs for council housing:

Quality of housing stock

ASHPs work best when producing heat at a lower temperature than traditional boilers. It is therefore essential that homes are well insulated and draught-proofed for the heating system to be effective.

The SCC council housing stock is predominantly old. Properties have generally been fitted with cavity wall insulation, loft insulation, uPVC double glazed windows and composite doors. However, many of the properties remain draughty due to difficulties in retrofit of insulation and do not meet current new build standards.

If SCC wished to pursue a programme of ASHP installations, it would be prudent to start with the newer properties first and/or those with higher quality insulation standards.

Existing heating systems

ASHPs can perform better with larger radiators, underfloor heating systems or warm air heating than with radiator-based systems because of the lower water temperatures required. The best time to consider an ASHP is therefore when the whole heating system is due for replacement. The majority of the boiler replacement programme in the next four years will also include replacement heating systems. However, ASHPs are very unlikely to be suitable for subsequent boiler only replacements.

Space availability

Space is needed outside the property where a unit can be fitted to a wall or placed on the ground. This should have plenty of space around it to get a good flow of air. A sunny wall is ideal.

Within the building, a water storage tank would be needed. This is not likely to be a key constraint since most of the original heating systems being replaced currently have hot water tanks.

Security

A unit located on the outside of each home would be inherently insecure compared to internal boiler installations. Sheffield council houses have suffered a history of boiler and copper pipe thefts from inside buildings. Security risk is therefore a consideration and may rule out ASHP installation particularly in high risk neighbourhoods.

However, Berneslai Homes have experience of installing ASHP in security cages in high risk neighbourhoods and have no reported incidents of vandalism or theft.

Existing fuel supply

The vast majority of council houses are supplied by mains gas. There are a small number of properties supplied by district heating schemes. Since gas is a relatively cheap fuel compared with electricity, high efficiency combination gas boilers may be cheaper to run than ASHPs.

Existing contracts

SCC has existing contracts for boiler and heating system replacements which cover the proposed 10,000 installations over the next four years. Provision of ASHP as the primary heat generator is not currently included in these contracts. SCC will need to establish is there is scope for variation in these contracts to facilitate ASHP installations under existing contract agreements.

Number of suitable properties

An estimated 29% of SCC domestic heating replacements or 714 out of 2,500 properties per year may be suitable for ASHP installations per year over the next four year period. This is based on the recommendations in the DECC methodology for assessing the potential ASHP resource:

- Only properties built since 1950 would be considered.
- 25% of flats and maisonettes considered suitable.
- 50% of bungalows considered suitable.
- 75% of houses considered suitable.

Experience from other local authorities would suggest that running a small pilot project (up to say 10-50 properties) would be beneficial before rolling out a more extensive programme. This would enable teething problems to be resolved to improve service delivery before committing to large scale deployment.

E3.6 Project finances

Capital investment

Indicative capital costs were provided by a range of other social housing providers. A replacement gas central heating system typically costs in the region of £3,000 - £5,000 compared with £9,000 for an ASHP system.

Annual costs

SCC annual cost of maintenance for the current stock of 37,500 gas boiler systems is in the region of £4.9 million. This is an average of £131 per year for each property which includes £68 for gas servicing and the remainder being flat rate and higher value repairs.

Where all gas services can be removed from a property (including other gas appliances such as gas fires and gas cookers), there may be a saving in gas servicing costs. Additionally, experience from other social housing providers suggests that ASHPs are more reliable than gas boilers and so there is a lower rate of repairs needed. However, this may in part be due to the lower average age of this equipment.

RHI income

Consumer body Which? provided a comparison of different energy costs and anticipated RHI payments from different sized installations. These are presented in the table below.

	1-bed semi-detached	2-bed semi-detached	3+ bed detached
Example annual heat demand (kWh)	9,000	13,500	23,000
Estimated annual RHI payment for an ASHP	£657	£986	£1,679
Estimated RHI payments for an ASHP over seven years	£4,599	£6,899	£11,753

SCC could claim this income for each installation to help recoup the additional cost of installing ASHPs.

Heating costs

One of the objectives of the boiler replacement programme is to save energy costs for council tenants. Savings for tenants are generated by installing modern, high efficiency equipment which replaces older boiler systems. When considering a switch to ASHP installations, it is useful to understand the relative cost of heat from gas boilers or ASHPs to understand the impact on council tenants.

Data from studies of actual in use performance of gas combination boilers and ASHPs has been used to calculate the cost of heat from each system as indicated in the table below. Heat from an ASHP is likely to be marginally more expensive (+8%) than heat from a gas boiler based on recent energy prices.

Gas boiler heat cost		ASHP heat cost	
Unit cost of gas	4.21 p/kWh[1]	Unit cost of electricity	13.52 p/kWh[1]
Gas combi boiler efficiency (actual in use efficiency)	82.5%[2]	ASHP average coefficient of performance	2.45[1]
Cost of heat from gas boiler	5.103 p/kWh	Cost of heat from ASHP	5.518 p/kWh

ASHP installations are more favourable when compared with other fuel sources available to off-grid properties.

E3.7 Benefits to the local economy

Skills development

By switching from conventional fossil fuel based heating to an air source heat pump supplier, there is not expected to be any net jobs growth in Sheffield. However, by adopting new technology, SCC would be supporting the

[1] Source: The heat is on: heat pump field trials, Energy Saving Trust, August 2013
[2] Source: In-situ monitoring of efficiencies of condensing boilers and use of secondary heating, DECC, June 2009

development of local companies to retrain or recruit staff to provide services in the green economy. This skills development would support the lowering of costs for other Sheffield residents who may also want to invest in ASHP technology.

Air quality

Replacing a single domestic gas boiler is unlikely to have much impact. However, by aggregating the savings in NOx, SOx and CO_2 across 10,000 homes, there would be a measurable improvement in local air quality.

E3.8 CO_2 savings

Replacing gas boilers with ASHPs could have a significant impact on carbon emissions from the city:

- Typical CO_2 savings for an average four-bedroom detached home with an average ASHP installation compared to an old gas non-condensing boiler are in the range 1.4 to 2.4 tonnes of CO_2 per year[2].
- CO_2 savings across a portfolio of 10,000 ASHP installations could be in the region of 14,000 tonnes of CO_2 per year.
- The CO_2 savings will increase year on year as grid electricity is progressively decarbonised (with increasing penetration of renewable electricity generation).

E3.9 Summary

Key points for SCC to note when considering whether to replace gas boilers with ASHPs in Sheffield's council housing stock include:

- ASHPs would be best considered in conjunction with existing heating system replacements, particularly where solar PV is to be installed.
- Newer and better insulated homes are more likely to suitable. ASHPs are particularly worth considering for new homes.
- The council has sufficient buying power and a big enough programme of heating system replacements to help kick-start the development of ASHP installation skills within Sheffield.
- Experience from other local authorities suggests that a strong education and technical support programme would be needed to support tenants in understanding and getting the best value from their ASHP systems.
- Renewable heat incentive payments are likely to be sufficient to cover the additional cost of installing ASHPs compared with gas boilers.
- The cost of heat for council tenants is likely to be slightly higher with ASHPs compared with gas boilers.

Appendix F

Beighton Closed Landfill Site: Renewable Energy Options Pre-feasibility Study

Sheffield City Council

Beighton Closed Landfill Site

Renewable Energy Options Pre-feasibility Study

0-7-8

Final Issue | 21 October 2014

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Contents

Executive Summary

Arup was commissioned by Sheffield City Council to provide a high level pre-feasibility assessment of renewable energy generation options at Beighton closed landfill site in Sheffield. The purpose of the study was to provide the council with an indication of technologies which may be suitable for development at the site and an initial indication of the relative financial returns from different proposed schemes.

A summary of the proposed renewable energy options for the site is shown in the table below. The most commercially and technically promising schemes are likely to be from landfill gas, anaerobic digestion and solar PV generation.

Proposed scheme	Installed capacity	Annual energy yield	Capital cost	Net annual income	Simple payback period
Landfill gas	100 - 330 kW_e	630 - 1,428 MWh_e	£270k - £350k	£25k-£30k	9-15 years
Anaerobic digestion	70 kW_e	587 MWh_e	£540k	£67k	8 years
Solar PV	715 kW_e	664 MWh_e	£900k	£72k	11 years
Wind energy	225 kW_e	340 MWh_e	£550k	£51k	11 years
District heating	250 kW_{th}	418 MWh_{th}	£681k	£12.5k	54 years
Hydropower	1 kW_e	8 MWh_e	£50k - £100k	£2k	35-100 years

If Sheffield City Council wishes to pursue any of these schemes, detailed investigations are recommended as follows:

- Early engagement with the local planning authority to identify any major planning constraints and help define the scope for any detailed feasibility assessments.
- Detailed feasibility study of landfill gas technology options to assess the long term technical and commercial viability following completion of the planned improvements to the gas collection system.
- Detailed feasibility study of other renewable energy options to include anaerobic digestion, wind energy and solar PV depending on the outcome of discussions with the local planning authority. Key aspects to consider will include:
    - Cost and capacity of a new grid connection agreement
    - Availability of waste feed stocks for anaerobic digestion
    - Investigation of ground conditions and foundation design options and costs for wind and solar PV options
    - Detailed investigation of other site constraints
    - Refined economic analysis

It is unlikely that a district heating network or hydropower generation would be feasible and no further investigations are recommended at this stage.

1 Introduction

Arup was commissioned by Sheffield City Council to provide a high level pre-feasibility assessment of renewable energy generation options at Beighton closed landfill site in Sheffield. The purpose of the study was to provide the council with an indication of technologies which may be suitable for development at the site and an initial indication of the relative financial returns from different proposed schemes.

This report outlines some of the key constraints and opportunities in relation to the site and provides an assessment of the following proposed schemes:

- Continued electricity (and heat) generation from landfill gas following expiry of the current concession agreement in 2015
- A district heating system to provide low carbon heat for a neighbouring housing development
- Anaerobic digestion using imported food and green waste
- Wind energy
- Solar photo-voltaics (PV)
- Hydropower on the Shire Brook

2 Site Description

Beighton Closed Landfill Site is located in the South-East of Sheffield on Beighton Road close to the A57. The site was historically used for coal mining and dumping of colliery spoil since the early 19th century. In the 1960s, the site was developed for waste disposal and parts of the site were used as a tip for household rubbish until its closure in 1999. Since then, Sheffield City Council has transformed the site into a local nature reserve, attracting wildlife and creating space for local residents to enjoy. Parts of the land are used for grazing for which the council receives a small income from the Higher Level Stewardship scheme.

Figure 1: General view of Beighton closed landfill site

The site contains a network of gas wells and pipe work which is used to collect and extract the landfill gas generated by the breakdown of the waste. The gas collection system is owned and maintained by the council. The landfill gas is fed to a gas engine which generates electricity supplied back to the National Grid. The gas engine is owned and operated by a specialist contractor under a 15 year concession agreement which is due to end in June 2015. Under the present arrangement, the council provides the gas free-of-charge to the contractor in return for a small royalty (1%) of any of the proceeds from electricity exports.

Sheffield City Council is interested to explore potential options for using the landfill gas once the concession agreement has expired in addition to other forms of renewable energy generation on the site.

2.1 Key enablers

There are several key enablers when considering an investment by the council in renewable energy generation at the site as outlined below.

2.1.1 Transport and access

The site has very good road transport links due to its proximity to the A57 and the M1. This has particular benefits during construction as any large scale plant and equipment could be relatively easily delivered to site without the need for costly road infrastructure modifications. Furthermore, the location on the edge of the city means that construction traffic would only affect a small number of residential properties close to the site entrance. There are also potential benefits for any installation which required regular ongoing traffic movements (for example deliveries of food waste or biomass).

2.1.2 Existing electricity substation

There is an existing electricity substation located on the site which is thought to have a capacity of around 1MW. This is significantly larger than is needed for export of electricity from the existing landfill gas engine. The available spare capacity would reduce the cost of connecting alternative renewable energy options.

2.1.3 Access to public borrowing

As a local authority, the council may be able to access public borrowing at more favourable rates than commercial investors.

2.1.4 Government incentives

The feed in tariff and renewable heat incentive schemes are specifically designed to make generation of small scale renewable electricity and heat financially viable in good locations when compared with fossil fuel alternatives. The developer receives index linked payments over a fixed period of time based on the amount of energy generated from renewable sources.

Energy generated from landfill gas does not qualify for feed in tariffs or renewable heat incentives. However, the developer can apply for Renewable Obligation Certificates which can be traded through an auction system to generate additional income for the scheme.

2.2 Key constraints

Similarly, there are several key constraints when considering an investment by Sheffield City Council in renewable energy generation at Beighton.

2.2.1 Landfill gas infrastructure

The existing landfill gas collection pipework is in poor condition. Sheffield City Council is currently investigating possible solutions to improve the gas collection system which is expected to result in higher gas flow rates at the compound. The existing concession agreement with CLP Envirogas Ltd. which operates the landfill gas engine is due to expire in June 2015. As a result, new landfill gas generation plant is likely to be commissioned before more reliable data is available on the gas collection rates. There will therefore be some uncertainty in the sizing of the new landfill gas plant.

Similarly, the leachate collection and treatment system is currently under investigation. There may be an opportunity to use any electricity generated on site to power the new and/or rehabilitated leachate treatment system.

2.2.2 Available resource

The suitability of the site for each of the different technologies and the available resource is considered in more detail in the following sections.

2.2.3 Planning

Any new development on the site would be subject to planning permission. The whole of the site is classified as green belt land with the majority also designated as a local nature reserve as shown in the extract from the Sheffield Local Plan below. Options with a smaller footprint and/or lesser environmental impacts may be considered by the planners as more suitable for development. Planning decisions are more likely to be favourable wherever additional benefits can be shown, for example by providing renewable heat or electricity to other local developments.

Early engagement with the local planning authority is recommended.

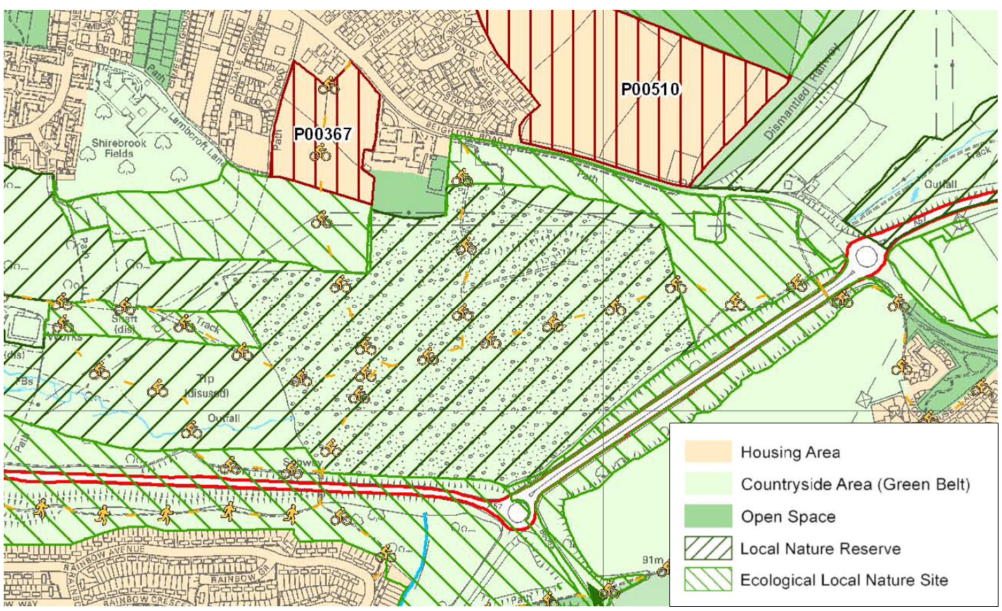

Figure 2: Extract from the Sheffield Local Plan, Sheet 7, February 2013

2.2.4 Proximity to residential properties

There are neighbouring housing areas to the north and south of the site. Any development would need to consider the impacts on residential properties. Noise, visual impact and traffic movements would need to be carefully considered.

2.2.5 Security

Public access to the site is actively encouraged through a network of maintained footpaths. Plant and equipment would need to be suitably protected with secure fenced compounds to prevent public access and reduce the risk of vandalism, theft, etc.

2.2.6 Other land uses

The use of the land as a local nature reserve and for grazing may not be compatible with certain forms of renewable energy generation. Work is taking place to improve the area for the local community and wildlife so that the site can be easily managed and looked after. This includes fencing off some sections in order to stop ground nesting birds and other wildlife from being disturbed, as well as protecting the gas network from vandalism. The impact of any renewable energy generation should be considered in relation to existing land uses.

3 Renewable Energy Options

3.1 Landfill gas generation

The landfill site at Beighton was in operation from 1987 to 1998 and continues to generate landfill gas today. The landfill gas management system, which currently combusts the landfill gas to produce electricity for export to the National Grid, is operated by CLP Envirogas Limited. With this concession agreement due to end in 2015, there is a potential for the council to install their own landfill gas utilisation plant and generate heat and electricity to create a long-term revenue stream.

The future landfill gas generation rates were estimated and utilisation options developed to understand the potential energy generation output from site.

3.1.1 Available resource

The estimated landfill gas generation rate at Beighton peaked at 733 Nm^3/hr in 1998, after which the rate began to decline steadily.[1] The most recent gas generation and gas collection figures[2] are presented in Table 1 which shows a clear decline in both gas generation and gas collection efficiency.

Year	Gas Generation from GasSim model (Nm^3/hr)	Actual gas collection (Nm^3/hr)	Gas Collection Efficiency
2011	272.9	165	60%
2012	254.7	122	48%
2013	237.7	58	24%

Table 1: Gas generation rates and actual gas collected at Beighton 2011-2013

The landfill gas generation rates are summarised in Figure 3 which shows an exponential decay curve plotted across the available data points provided starting with the peak generation in 1998. The future generation rates are projected forward by 25 years. The accuracy of these predictions could be further improved if presented with more historical generation rate figures. As an illustration, we have also shown future gas collection rates based on a conservative gas collection efficiency of 40%.

There is significant room for collection improvement through refurbishment of the existing gas collection system. The council has already embarked on a programme of works to upgrade the gas field in order to reduce air ingress, stop lateral migration outside of the site and secure a viable gas resource for the next 10 years.

[1] Golder Associates. Beighton Landfill Site, LFG Management. July 2011. Report No. 11514290085.500/C.0

[2] Ground Gas Solutions Ltd. Gas Management Review: Beighton Landfill Site, Sheffield. June 2014. Report No. GGS471GMR01r1

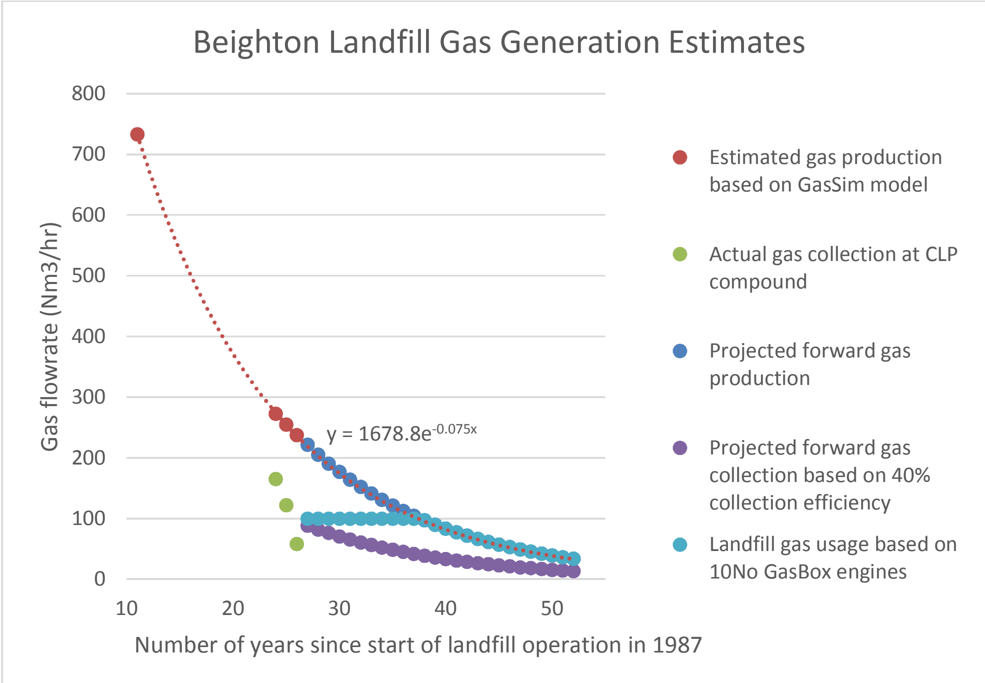

Figure 3: Predicted future landfill gas generation at Beighton

The methane concentration at the boreholes was measured by CLP Envirogas Ltd every month and the data collected between September 2003 and June 2010 is summarised in Figure 4. The graph shows significant fluctuations with concentrations varying from 25.7% to 51.9% v/v but the overall trend appears to be increasing. The average methane concentration of 33% v/v has been used for the basis of the landfill gas utilisation design.

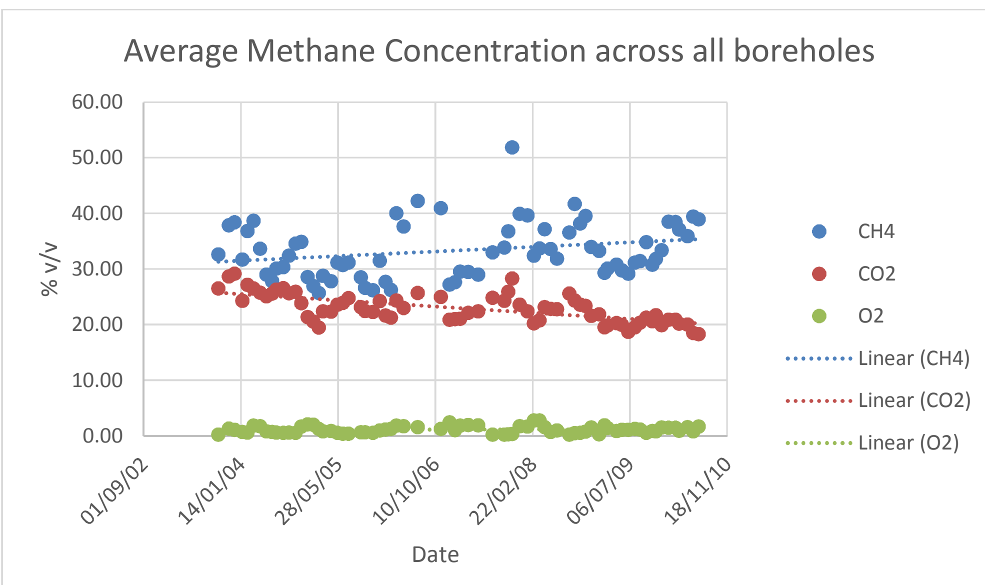

Figure 4: Average methane concentrations at Beighton in 2003-2010

The theoretical power available in the landfill gas based on 33% methane is summarised in Table 2 based on a calorific value of 37 MJ per m^3 of methane.

Year	**Gas generation from GasSim model (Nm^3/hr)**	**Power available in the gas (kW)**
2011	272.9	925
2012	254.7	864
2013	237.7	806

Table 2: Power available in the landfill gas at Beighton

3.1.2 Available technologies

Arup investigated the available technologies for the conversion of landfill gas to electricity considering the decreasing volumes and methane concentration. The two most adaptable technologies were found to be the GasBox Stirling engine and the Jenbacher gas engine.

Option 1: GasBox Stirling engine
Landfill Gas Systems distribute a low calorific gas engine called the GasBox Stirling engine which is manufactured by a Swedish-based company Cleanergy. The gas engine can be run with a landfill gas with methane concentrations ranging 18-100% at a flow rate of approximately 10 Nm^3/hr. A system would be provided with several GasBox engines operating in parallel installed within a standard shipping container. The engines are typically remotely controlled so there is no need for a dedicated staff member to be on site; only monthly visual inspections are recommended to be carried out.

Based on the landfill gas predictions shown previously, it is possible to continue operating the GasBox engines over the next 25 years when gas collected is estimated to be 10 Nm^3/hr. Over the engine asset life of 25 years, it is expected that the engines will be switched off one at a time to match landfill gas supply.

Option 2: Jenbacher internal combustion engine
The Jenbacher engine has potential to combust the landfill gas generated at Beighton. One engine has the capacity to serve the gas collected from the entire site. Although the Jenbacher engine has a lower thermal efficiency, it is known to have a higher electrical efficiency than the GasBox engines of up to 38.7%.

From previous experience, the Jenbacher gas engine has had difficulty coping with combusting of low calorific gas. In addition, the engine can only be de-rated to 136 Nm^3/hr after which it might will no longer maintain steady operation or may need to be supplemented with natural gas.

Option 3: Biogas to grid
Upgrading the landfill gas for grid injection is unlikely to be viable based on the current landfill gas volumes and quality. The biogas upgrading plant typically becomes financial unviable at flow rates of less than 300 Nm^3/h. There are also challenges with increasing a low-calorific landfill gas with a methane concentration of 33% to 98% v/v. Apart from the upgrading plant itself, there are substantial capital and operating costs associated with gas compression and grid

connection which are dependent on the pressure of the gas mains and the proximity of the nearest grid connection point.

This option could be explored at a later stage if equipment becomes cheaper and more flexible.

Option 4: Flare
All of the above options would also require a flare costing in the region of £40k. This cost was not included in the economic assessment as it would be needed regardless of the technology adopted.

3.1.3 Economic assessment

Option 1: GasBox Stirling engine
Assuming that the gas collection system is improved to near 100% through refurbishment, it is possible to operate 10 GasBox engines with a flare system which is able to consume 100 Nm^3/hr of landfill gas.

The GasBox engines will have an electrical output of 72 kWe and a thermal output of 250 kWth. The engines may generate up to 630 MWh of electrical energy and 2,190 MWh of thermal energy per year. This generation rate is expected to last until 2024 after which the engines will begin to shut down one at a time to match declining landfill gas generation rates. At this point, there may be an opportunity to sell off individual engines or use them on another site to recover some of the residual value when they are no longer required.

Table 3 is a summary of the cost analysis based on the operation of 10 GasBox engines at maximum throughput.

Capital Cost	£356,000	2 Containers of 5 GasBox Stirling Systems
Maintenance Costs	£10,000	Annual maintenance service from Landfill Systems
Revenue from financial incentives – electrical	£5,040	0.2 ROC per MWh and £40 per ROC
Revenue from electrical export	£30,051	£47.70 per MWh electricity
Simple payback	15 years	

Table 3: Summary of the costs, revenues and payback period for 10 GasBox engines

In this scenario, any heat generated would need to be dissipated through a heat dump.

Option 2: Jenbacher internal combustion engine
Assuming similar assumptions on the gas collection system as with Option 1, the Jenbacher engine can be operated at a landfill gas flowrate ranging from 136 to 250 Nm^3/hr. The peak electrical output would be 330kWe with a corresponding peak heat output of 262kWth.

The cost analysis in Table 4 is based on the operation of one Jenbacher engine continuously at minimum throughput which reflects a mid-way scenario payback period. The corresponding electrical output would be 163 kWe with a heat output of 124 kWth. The payback period could be reduced if it is decided to divert the landfill gas from into the gas engine at a higher rate although this would not be possible beyond year six of operation. In year seven, it may be necessary to start importing natural gas from the grid in order to keep the engine running. The cost of the associated infrastructure and gas purchase is not currently included in the economic analysis presented below.

Capital Cost	£270,015	GE Jenbacher Engine JGC 208
Maintenance Costs	£49,600	Annual maintenance service from Clarke Energy
Revenue from financial incentives – electrical	£11,423	0.2 ROC per MWh and £40 per ROC
Revenue from electrical export	£68,110	£47.70 per MWh electricity
Simple payback	9 years	

Table 4: Summary of the costs, revenues and payback period for one Jenbacher engine JGC 208

Similar to the GasBox option, any heat generated would need to be dissipated through a heat dump. This option has a shorter payback period due to the lower capital cost and higher electrical efficiency of the plant. However, the plant is likely to have a much shorter asset life than the GasBox option.

3.1.4 Landfill gas generation summary

The council has potential to continue generating energy from combustion of the landfill gas at Beighton with consideration of the declining landfill gas flow rates. The simple payback periods of 15 years and 9 years are within the asset life of the GasBox and Jenbacher gas engines. The GasBox engines appear to be the more attractive long term option due to the site being able to produce revenues from ROCs and electricity export until gas generation rate reaches 10 Nm^3/h. The Jenbacher engine can only operate down to a minimum flowrate of 136 Nm^3/hr and would need to start importing natural gas after approximately seven years.

Following completion of the planned improvements to the gas collection system, gas collection rates and methane concentration should be measured over as long a period as possible. A longer period will capture a wider range of atmospheric pressures and ground saturation conditions which will provide a more accurate basis for the selection of new generating plant. The observed data should be compared with modelled gas generation rates to assess the new gas collection efficiency such that more accurate future gas collection estimates can be developed.

Once more reliable future gas collection estimates are available, the above analysis should be refined. This should include an assessment of the technical suitability of the proposed generating plant for long term operation and a long term cashflow analysis and comparison of net present value for different technology options.

3.2 District heating

A new social housing development of 110 homes is proposed on a site adjacent to the Beighton closed landfill site. The location is shown by the area marked as P00367 on Figure 2 on page 5 which has a site area of 3.02ha.

The potential for developing a district heating system supplied from an energy centre on the Beighton closed landfill site has been investigated. An ideal site for a district heating scheme would be a new build development with a relatively high density of buildings and a consistent heating demand.

The waste heat available from the landfill gas generation plant gives a good opportunity for developing a district heating network on the neighbouring site.

3.2.1 Heat demand

In the absence of any available information about the proposed development, assumptions have been made about the number and size of the new properties as follows:

- 22 homes (20%) with two bedrooms
- 66 homes (60%) with three bedrooms
- 22 homes (20%) with four bedrooms

An assessment of the annual heat and electricity consumption for the development is summarised in the table below.

Property Size	No. of units	Area (m^2)	Heat (kWh/m^2)	Electricity (kWh/m^2)	Heat (kWh/yr)	Electricity (kWh/yr)
2 Bed house	22	61	46.1	34	61,871	45,628
3 Bed house	66	92	42.9	34	260,233	206,448
4 Bed house	22	116	37.4	38	95,558	95,976
Total	**110**				**417,662**	**349,052**

Table 5: Estimated annual heat and electricity consumption from proposed housing development

A standard hourly heat load profile based on typical daily domestic heat usage was used to estimate the peak heat demand. The standard profile was adjusted such that total annual heat consumption was equal to 417,662 kWh/year. The graph below shows the estimated average hourly heat load profile for a typical day in each month of the year.

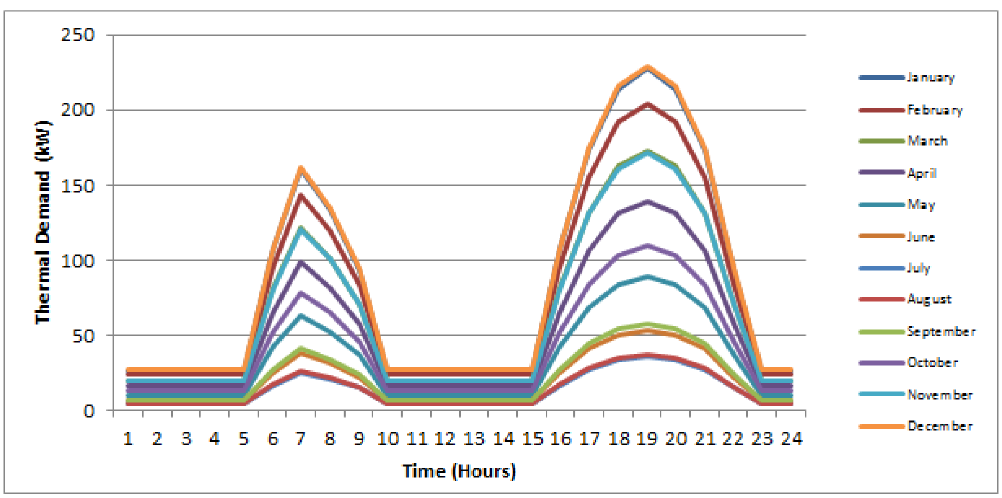

Figure 5: Estimated heat demand profile for the proposed housing development

The peak thermal demand is depicted in the graph as 230kW occurring at 18:00 in December. However this is the average maximum demand in winter, so to avoid underestimating the actual peak heat demand of the new residential development a safety margin of 1.5 times the peak thermal demand was applied giving a maximum heat demand of 345kW.

3.2.2 Available technology

There are a number of potential technologies which would be suitable to provide heat to a district heating network.

Landfill gas CHP
It is expected that the total heat demand for the housing development could be provided by the landfill gas plant described above (except in extreme winter weather scenarios). If needed, it would be possible to blend the landfill gas with natural gas to increase the calorific value and heat generation to cope with high district heating demands during winter periods.

During off-peak heat demand hours there would be a surplus amount of heat. Ideally this would be used for other site processes or an extended district heating network. If not, it would have to be rejected by the CHP heat dump radiator and by CHPQA assessment may prevent the proposed energy centre from receiving a Renewable Obligation revenue.

Standby boilers
It is likely that gas-fired boilers would be required to provide standby capacity for when the CHP is offline and top-up to cover the maximum heat demand. For the purposes of this study it has been assumed that two gas fired boilers would be required each rated at 350 kW_{th}. This would ensure 100% availability of heat supply for the housing development.

Biomass boilers
Biomass boilers could be considered as an alternative to gas-fired boilers.

3.2.3 Energy centre and district heating network

A new energy centre to house the heating plant would preferably be constructed and situated as close as possible to centre of the P00367 site location. An additional natural gas supply would need to be provided to the energy centre.

Pre-insulated buried pipework would be needed to distribute low temperature hot water around the proposed housing development. In the absence of a site layout for the proposed housing development, assumptions about pipework lengths have been made in the economic assessment. This includes an assumption that heat losses along the district heating pipework would be less than 10%.

3.2.4 Economic assessment

A summary of the economic calculations is provided in Table 6 below. We have used benchmark capital and operational costs which have been developed based on industry guidance and past Arup experience of district heating solutions. The analysis assumes that costs associated with the landfill gas CHP plant has already been included.

Annual energy sales from district heating system	418 MWh_{th}	Based on estimated heat demands detailed above
Capital cost	£681,000	For 2 gas boilers, energy centre and district heating pipework. Cost excludes the CHP which is assumed to be already provided.
Operational cost	£10,000	Annual maintenance for boilers and district heating system
Annual income	£22,554	Assuming 100% of heat supplied by waste heat from landfill gas, heat sales at 5p/kWh and ROC income at 0.1 ROC per MWh and £40 per ROC
Simple payback	54 years	

Table 6: District heating summary of economic assessment

The payback period could be substantially improved by increasing the size of the district heating network to include a higher heat demand and thus increase heat sales. This may not require significant additional infrastructure or running costs except for an extension to the district heating pipework. Another option would be to consider direct sales of electricity to the housing development. Assuming electricity could be sold to residents at 10p/kWh compared to the feed in tariff export rate of 4.77p/kWh, the additional income raised would reduce the payback period to 22 years. A third alternative would be to investigate selling heat at a higher tariff than 5p/kWh.

3.2.5 District heating summary

A new energy centre and district heating network to supply 110 homes with low carbon heat appears to be technically feasible. However, the current economic analysis indicates very poor financial viability unless additional revenue can be found from additional heat sales, electricity sales and/or increased tariffs.

There may be some value in updating the analysis when more information about the proposed development and the landfill gas availability becomes available. However, no further investigations into district heating are recommended at this stage.

3.3 Anaerobic digestion

An anaerobic digestion (AD) plant has to meet a number of general siting criteria which includes connection to the local electrical distribution system, availability of space, good access to a primary road network and close proximity to waste as AD feedstock. The current infrastructure at Beighton satisfies these criteria and presents an opportunity for development of a waste AD facility.

We have assessed the available AD feedstock resource within Sheffield and provided an economic assessment of one potential scenario.

3.3.1 Available resource

The two most widely available feedstock types available within Sheffield were identified to be:

1) Food waste from restaurants, canteens or other similar establishments

2) Green waste such as grass cutting from parks and woodland areas

For the design basis of the AD plant, we have assumed that 1,000 tonnes per year of food waste will be available from a single lorry doing collection rounds within Sheffield. This is equivalent to around 3 tonnes of food waste collected per day.

The information on the exact volume of green waste available still needs to be carried out through a separate study by the council. Therefore, we have applied a 40:60 food waste to green waste ratio for optimum biogas production based on scientific literature.[3] This is equivalent to 1,500 tonnes of green waste collected per year.

3.3.2 Energy yield

Food waste and green waste are estimated to have a biogas yield of 160 and 60 m^3/tonne, respectively. The resulting combined feed is estimated to have a methane content of 65% v/v. Based on a calorific value of 37 MJ/m^3 of methane, an overall gross calorific value of the feed is estimated to be 191 kW or 1,673 MWh per year.

The biogas from the digester will be fed into a CHP engine to produce electricity and thermal energy. Based on typical CHP electrical efficiency of 35% and thermal efficiency of 45%, 67 kW of electricity and 86 kW of thermal energy can be generated which will be offset by the heating requirements of the digester.

A digester required to process the 2,500 m^3 of waste per year will have a volume of 860 m^3. Assuming the use of biogas for heating, all of the thermal energy produced by the digester itself will be required to maintain a temperature of 35°C required for the digestion process. No further natural gas is needed to supplement process heating.

The limiting factor to the design of the AD plant is the capacity of the existing substation on the site which allows the council to export 1 MW of electricity to the grid. This indicates that if there is more food waste and green waste available than initially estimated, it is still possible to design multiple or larger AD plants which can provide greater energy yields at Beighton. It would be possible to build a modular AD system to increase the capacity of the plant over time as a larger waste stream becomes available.

[3] Chen et al. (2014) Comparison of high-solids to liquid anaerobic co-digestion of food waste and green waste. Bioresource Technology. ed. 154 p. 215-211.

3.3.3 Economic assessment

Table 7 summarises the cost analysis based on the operation of an AD plant with a throughput of 2,500 tonnes per year.

Capital Cost	£536,000	AD Plant
Maintenance Costs	£26,800	Annual O&M Costs
Revenue from financial incentives	£65,794	11.21p/kWh electrical output -Feed in Tariff
Revenue from electrical export	£27,996	£0.0477/ kWh electricity
Simple payback	8 years	

Table 7: Anaerobic digestion summary of economic assessment

The best revenue stream was chosen for the economic assessment of the AD option. New AD installations can claim revenues through the Renewable Obligation or the Feed-in-Tariff schemes. Under the ROC banding, AD is eligible for double ROCs which equates to an annual revenue of approximately £47,000. The Feed-in-Tariff revenue is higher at £65,794 and offers a guaranteed income for the developer so has therefore been used in the analysis.

The payback of 8 years generated by the costs analysis is acceptable but the actual payback time could potentially increase depending on the additional capital costs associated with the required treatment of the feedstock prior to digester feeding. This is decided by the quality of the food waste and green waste collected. The degree of pre-treatment can be identified at a later stage by characterisation of the feed. Woody and larger green waste will need to undergo a size reduction process such as maceration, whereas food waste may need to be screened to remove non-biodegradable packaging material. Maceration of food waste may also be required.

3.3.4 Anaerobic digestion summary

The location and existing infrastructure available indicates there is potential for the use a waste anaerobic digestion operation at Beighton which could produce a simple payback period of 8 years. If this is considered reasonable, it is suggested that further investigation of the feed stock availability and biogas yield is carried out to determine the technical viability of the scheme and provide a more accurate estimate of the commercial aspects of the scheme.

3.4 Wind energy

The potential wind resource and feasibility has been investigated at the Beighton Landfill site. Ideal conditions for a wind turbine would be a large windy site with good access, straightforward ground conditions and a location not too close to houses, roads or railways. Consideration also needs to be given to potential impacts on local ecology, birds, cultural heritage assets, fixed telecommunication links and aviation radar.

3.4.1 Site constraints

Arup produced a high level constraints map for the Beighton closed landfill site showing the available area for a potential wind turbine as shown in Figure 6 below. The site is bounded by residential properties to the north and south which limits the potential for wind energy development due to visual impact and shadow flicker issues. The proximity to the A57 further limits the available area for development due to turbine fall-over distance requirements.

Figure 6: Potential nearby constraints for a wind energy development at the Beighton Landfill site

The proposed turbine position is located within the deepest part of the landfill site. This would add significant additional cost for the turbine foundations which would need to be correspondingly deeper.

Given the site constraints, a relatively small single turbine is likely to be the most suitable for the site.

3.4.2 Wind resource

The available wind resource was estimated using the NOABL (Numerical Objective Analysis Boundary Layer) wind speed database from the Department of Energy and Climate Change. The NOABL database estimates wind speeds at heights of 10, 20 and 45 metres above ground. It is based on the Ordnance Survey grid system and gives speed estimates at grid points 1 kilometre apart.

The site has a relatively low wind speed estimated to be about 4.7m/s at 25m above ground level.

3.4.3 Energy yield

The energy yield has been estimated based on an Endurance X35 wind turbine with a maximum tip height of 50m and an installed capacity of 225kW. The estimated NOABL wind resource was extrapolated to 4.99m/s at the proposed hub height of 30.5m. A wind turbine of this scale would generate up to 340,000 kWh per annum. This demonstrates a capacity factor of approximately 17%.

3.4.4 Economic assessment

Indicative budget estimates for the capital cost and operation costs have been based on figures provided by wind turbine supplier based on a standard installed cost, excluding on site electrical upgrade work.

Annual Energy Yield	340,000 kWh	Based on the NOABL wind speed of 4.7m/s at 25m extrapolated to a hub height of 30.5m.
Annual Income	£61,000	Based on a Feed-in Tariff rate of £0.1334/kWh and an export rate of £0.0477/kWh.
Indicative operation and maintenance cost	£10,000	
Capital Cost	£500,000-£550,000	Based on manufacturer costs with an allowance for additional civil costs and electrical costs.
Simple Payback	10-11 years	
Internal Rate of Return (IRR)	5.4%	Using a project life of 25 years

Table 8: Wind energy summary of economic assessment

3.4.5 Wind energy summary

It is not recommended to pursue the installation of a wind turbine at Beighton due to the following factors:

- Low wind resource of 4.99 m/s at the proposed hub height
- Low capacity factor in the order of 17%
- Close proximity to houses prevents development on large parts of the site
- Proximity to houses could lead to planning objections
- Challenging ground conditions

3.5 Solar PV

The potential for developing a ground mounted solar photovoltaic (PV) scheme on the Beighton Landfill gas site has been investigated.

The amount of power generated by a PV scheme is directly proportional to the amount of sunlight (irradiance) that is available at the site. An ideal site would be south facing, level ground and have no shading obstacles in the site vicinity.

3.5.1 Available resource

The simulation process was undertaken by Arup using the industry standard PVSyst V6.24 software package.

Arup has used annual global horizontal irradiation data for the potential facility at 936 kWh/m^2/year from the Meteonorm V7 data source which was available for the period 1986 to 2005. Meteonorm data is gathered by interpolating results from records of the nearest weather stations, and using satellite data where weather station records are not available.

This was validated by comparing the data with NASA-SSE, PVGIS-Classic and PVGIS-SAF weather data sources. The comparison showed that the value for the annual global horizontal irradiation provided by Meteonorm is within 6.90% of PVGIS-SAF, 1.3% of NASA-SSE, and 0.7% of PVGIS-Classic data. These differences are within a reasonable range and the Meteonorm data is thus considered appropriate to be used for the yield simulation.

This is confirmed in Figure 7 shown below, which shows that the Meteonorm data closely tracks the three alternate sources, except in the summer months, where NASA and PVGIS-Classic are more conservative and PVGIS-SAF is higher.

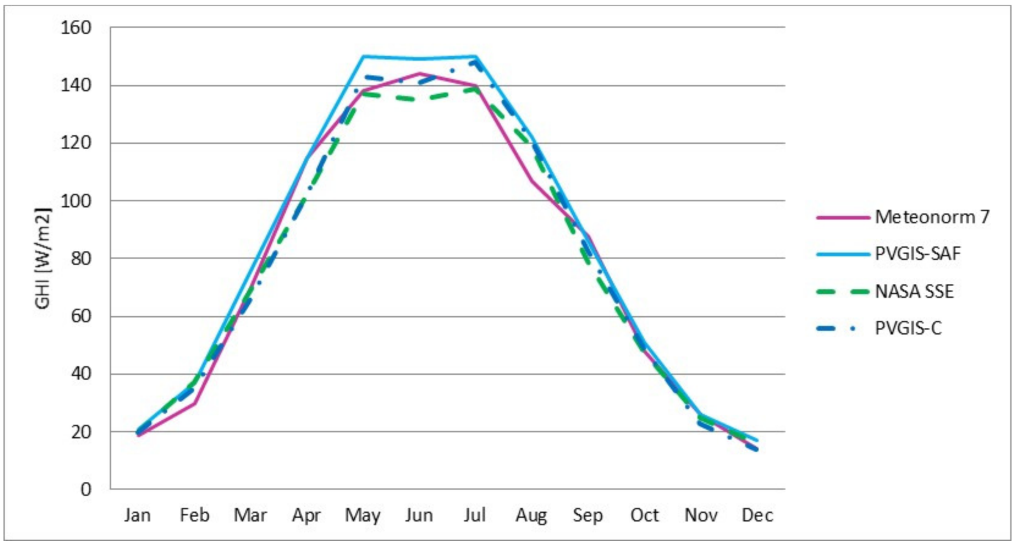

Figure 7: Comparison of Monthly Irradiance Data

Arup has chosen to use the Meteonorm data for the yield simulation due to that fact that Meteonorm is considered to be the most robust data source available. The uncertainty associated with the global horizontal irradiation is considered to be less for Meteonorm data than for the other three data sources.

We note that, in the case of this site, the Meteonorm uncertainty is still relatively high as the surrounding irradiation measurement stations are relatively far from the site.

3.5.2 Energy yield

Due to the site topography and the access required to the existing landfill gas infrastructure it was only considered feasible to deploy PV arrays on distinct plots across the site. The layout of the scheme in shown in Figure 8 below.

Figure 8: PV Scheme Layout

The general configuration of the system is summarised in Table 9 below.

PV Module Specification	
Manufacturer	Canadian Solar
Model Number	CS6X-310P
Nominal Rated Power (STC) [Wp]	310
Inverter Specification	
Manufacturer	ABB
Model Number	PVS800-57-0315kW-A
Nominal Rated AC Power (@50°C) [kW]	315
General Configuration	
Nominal Capacity (DC) [kWp]	715
Inverter Capacity (AC) [kW]	630
Number of PV Modules	2,304
Number of Inverters	2
Modules per String	18
PV Module Inclination Angle	30°
Pitch (row separation, centre to centre) [m]	7.0

Table 9: Summary of proposed PV system

Based on the assumed layout, a maximum possible plant size of 715 kWp, estimated irradiance of 937 kWh/m^2, a module efficiency of 16.16% and a performance ratio of 84.4% the yield would be approximately 664 MWh per year.

3.5.3 Economic assessment

In order to estimate the capital costs associated with the potential PV schemes a benchmark cost has been developed based on industry guidance and past Arup experience. This benchmark (£1,200/kWp) has been developed to give an estimate of a total installed capital cost for a scheme.

O&M costs have been determined based on past experience of PV solutions. This cost is included to cover annual cleaning of the PV systems and routine maintenance checks.

Annual Energy Yield [MWh]	664	Based on irradiance = 937kWh/m2, module efficiency = 16.16%, performance ratio = 84.4%
Annual Income	£85,555	Based on Feed in Tariff rates of 6.83p/kWh generation tariff and 5.6p/kWh export tariff
Capital Cost	£900,000	Based on industry benchmarks of £1,200/kWp
Operational Cost	£13,500	Based on industry benchmarks of £18.00/kWp per annum
Simple Payback	11 years	
Internal Rate of Return (IRR)	7.54%	

Table 10: Solar PV summary of economic assessment

3.5.4 Solar PV summary

The technical assessment concludes that a 715 kWp ground mounted PV installation could potentially be developed on the Beighton Landfill Gas site.

Based on the assessment undertaken it appears that the schemes will provide a rate of return of around 7.5% and an associated payback period in the order of 11 years.

3.6 Hydropower

The Shire Brook has been diverted through a culvert which flows through the middle of the site from west to east. The potential for hydropower generation on the brook has been investigated.

The amount of power generated by a hydropower scheme is directly proportional to the product of the available head (height) and the flow. An ideal site would have a consistent flow falling through a significant drop in level over as a short distance as possible.

3.6.1 Available head

The invert of the culvert drops approximately 10m from the upstream to the downstream end of the site over a length of approximately 1km. This gives a relatively low gradient of approximately 1 in 100 which does not particularly lend itself to hydropower development.

Furthermore, it would be necessary to prevent damage to the culvert which could lead to either leachate leaking into the watercourse, or the watercourse leaking into the leachate collection system. We have therefore assumed that it would not be possible to internally pressurise the culvert. The maximum head available would need to be based on the diameter of the culvert at the downstream end. A weir would need to be constructed at an appropriate height (approximately 1.6m) in order to impound the water and generate a head drop over the weir. Water would collect in the downstream end of the culvert but would not pressurise the pipe. The available head for hydropower generation would be limited to a maximum of 1.6m.

3.6.2 Available flow

According to Environment Agency guidance for hydropower developments in England, the maximum flow which can be extracted from a watercourse is usually based on the 50th percentile flow, or Q50. There is no available gauged flow data for the watercourse so it is difficult to accurately determine the available flow. An existing Environment Agency river model indicates a flow of 0.154m^3/s as the Shire Brook flows into the River Rother approximately 2-3km downstream during flood conditions. On the day of the site visit, the flow of the stream was estimated at no more than 0.1m^3/s. This figure was used in the analysis as the average flow.

3.6.3 Energy yield

Based on the available head of 1.6m, estimated average flow of 0.1 m^3/s and overall plant efficiency of 60%, the maximum possible turbine size was estimated as 1kW. This would yield approximately 8,000kWh per year.

3.6.4 Economic assessment

Due to the low energy yield, very crude estimates were developed for capital costs, operational costs and revenues in order to provide an illustration for comparison with other technologies.

Installed capacity	1 kW	
Annual energy yield	8,000 kWh	Based on head = 1.6m, flow = 0.1m^3/s, plant efficiency = 60%
Annual income	£1,900	Based on Feed in Tariff rates of 19.01p/kWh generation tariff and 4.77p/kWh export tariff
Capital cost	£50k - £100k	
Operational cost	£500 - £1,000	Based on a 1hr visit to clean the screens every 1-2 weeks costed at £20/hr
Simple payback	35-100 years	

3.6.5 Hydropower summary

Since the site has neither a significant flow nor much available head, it is very unlikely that hydropower would be feasible at Beighton. This is indicated by the very poor simple payback period.

No further investigations into hydropower generation are recommended.

4 Conclusions and Recommendations

A summary of the proposed renewable energy options for Beighton closed landfill site is shown in the table below. The most promising schemes are likely to be from landfill gas, anaerobic digestion and solar PV generation.

Proposed scheme	Installed capacity	Annual energy yield	Capital cost	Simple payback period
Landfill gas	100 - 330 kW_e	630 - 1,428 MWh_e	£270k - £350k	9-15 years
Anaerobic digestion	70 kW_e	587 MWh_e	£540k	8 years
Solar PV	715 kW_e	664 MWh_e	£900k	11 years
Wind energy	225 kW_e	340 MWh_e	£550k	11 years
District heating	250 kW_{th}	418 MWh_{th}	£681k	54 years
Hydropower	1 kW_e	8 MWh_e	£50k - £100k	35-100 years

Table 11: Comparison of renewable energy options for Beighton closed landfill site

Depending on the appetite for development from Sheffield City Council, further investigations are recommended as outlined below.

If the council is interested in developing of any of the proposed schemes, we would recommend early engagement with the local planning authority prior to commissioning more detailed investigations. This would enable the council to identify any potential showstoppers and help define the scope for any detailed feasibility assessments. Early engagement activities would typically include:

- Desk based study to examine existing planning policy documents and council aspirations for the site; and
- Pre-application discussions and meetings with the local planners to determine the relative suitability of different options for the site from a planning perspective.

There are good prospects for the continued generation of electricity from **landfill gas** at Beighton. Further investigations into the long term technical and commercial viability of landfill gas technology options should be made following completion of the planned improvements to the gas collection system.

A **district heating** network to supply a neighbouring housing development would be technically feasible using waste heat from the landfill gas plant. The economic analysis indicates very poor financial viability and no further investigations into district heating are recommended at this stage.

Anaerobic digestion appears to offer reasonable financial returns provided that food and green waste feed stocks can be sourced locally. More detailed investigation is recommended to provide a more accurate analysis of the technical and commercial viability of the scheme.

Installation of a medium scale **wind turbine** may be possible although does not appear to be a good prospect given the relatively poor wind resource, challenging ground conditions and proximity to houses which could lead to planning objections. If discussions with the local planning authority are positive, there may be some value in more a detailed feasibility assessment to investigate key site constraints in more detail such as ground conditions, cost of foundations, impact on fixed telecommunication links and aviation constraints.

A ground mounted **solar PV** installation could potentially be developed with reasonable financial returns. A detailed feasibility study would need to investigate key site constraints in more detail such as ground conditions, cost of foundations, grid connection and shading constraints.

It is very unlikely that **hydropower** generation would be feasible and no further investigations are recommended.