Bigby Parish Council

Renewable Energy Strategic Vision

Strategic Energy Prospectus for Bigby Parish

March 2022

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Contents

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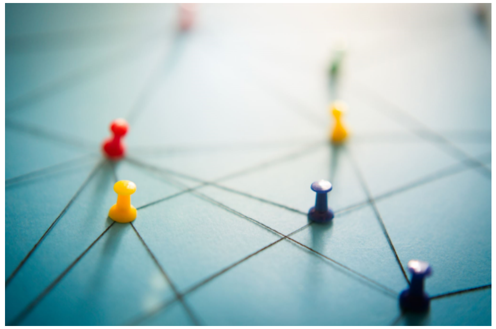
Glossary

Glossary of terms

Term	Definition
ASHP	Air Source Heat Pump
CCUS	Carbon Capture Utilisation and Storage
COP	Coefficient of performance
GSHP	Ground source heat pump
IRM	Integrated Risk Matrix
BEIS	Department for Business, Energy and Industrial Strategy
O&M	Operation and maintenance
PV	Photovoltaic
NGET	National Grid Electricity Transmission
GSHP	Ground Source Heat Pumps

Executive Summary



Executive summary

Supported by the Midland Energy Hub, a BEIS organisation supporting the LEP and local authorities, Bigby Parish Council have received funding support through the Rural Communities Energy Fund to explore the development opportunities for renewable energy projects utilising local natural resources in the Parish.

Arup are ideally placed to help design the art of the possible and are pleased to have been selected to undertake this formative energy strategy for the Parish Council in what is a strategically important region of South Humber. A simple three stage process has been adopted:

Familiarisation with the Parish geographic, demographic and wider economic make-up along with engagement with stakeholders and the Parish Council has provided a clear vision of the natural capacity to embed renewable energy infrastructure serving demand growth in the Parish.

The vision for Bigby has been formed to accommodate temporal, technical, environmental and geographic constraints without compromising on innovation and aspirations to make the step change that climate change mitigation requires globally, nationally and locally.

The vision for Bigby has been formed around identifying relatively small existing electricity and heat demands of residential and commercial buildings, examining the potential to expand the demand portfolio beyond the immediate community to surrounding existing commercial demands and to further grow demand by utilizing available land for synergistic business developments.

The vision for the renewable energy development opportunities hinges on utilizing the land area available for electricity generation via PV and wind and simultaneous use of ground energy for heat provision via ambient networks serving heat pumps. The land area made available by the Turnbull Estate presents a significantly larger capacity of renewable electricity and heat potential than the demand growth scenarios require. Over 70MWe of renewable PV electricity capacity could be built on only a third of the available land. Ground source heat captured by closed loop borehole arrays would satisfy all known and potentially developed demands

However, the ability to capitalize on the maximum renewable potential is limited by the constraint posed by the inability of the Northern Power Grid to accept exported power in the short-term. Private wire networks serving the existing and demand growth scenario along with battery storage are therefore envisaged and are recommended from a economic perspective regardless of and prior to any reinforcement of the NPG network that might happen.

The strategy for Bigby is therefore one of phased development over 5 year sprints considered in the short-term (2022-’27), medium-term (’28-’33) and long-term (’34-’39).

As illustrated below this study has identified for Bigby and surrounding community the magnitude of the art of the possible for renewable generation, demand growth, net zero carbon and investment prospect. The investment prospect is presented for the renewable energy developer market and the energy intensive business developer markets with potential for synergistic operations. In this regard this study serves as a bold prospectus to all interested parties.

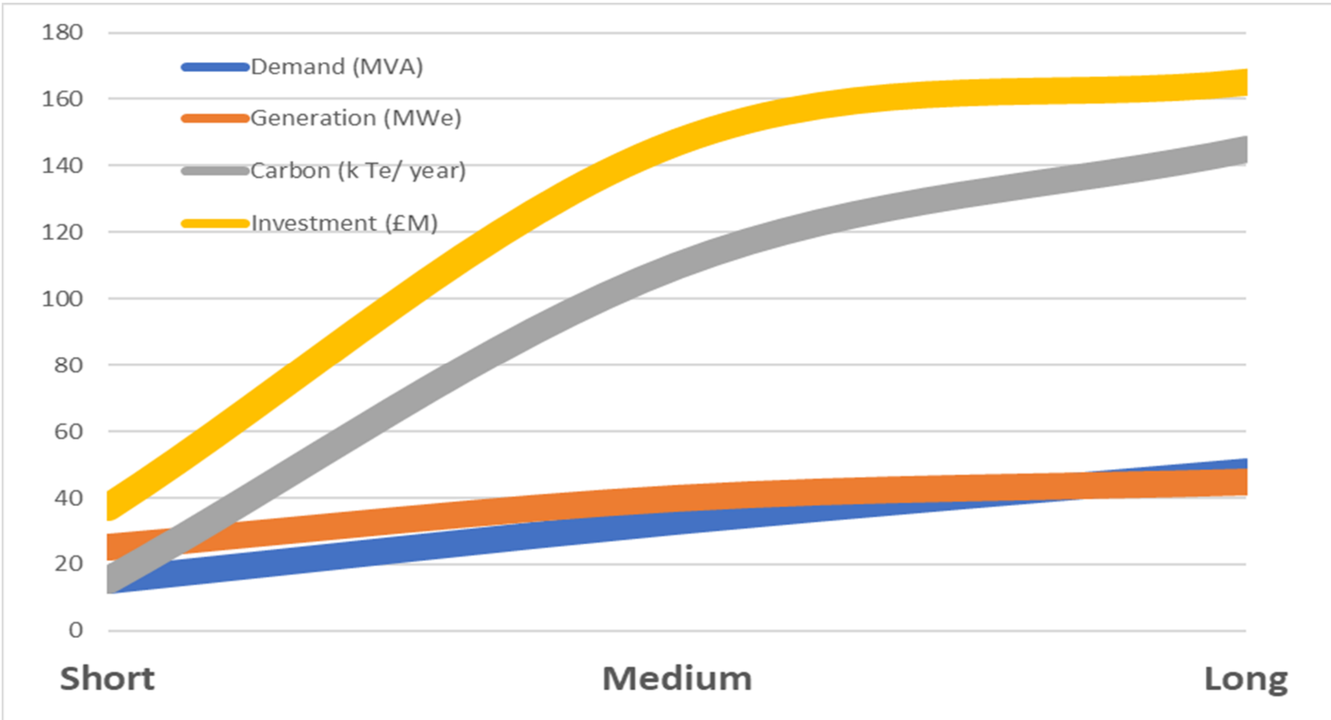
Executive summary

The strategy taking shape for Bigby should now be progressed by a focused techno-economic feasibility of the prioritised opportunities and stakeholder engagement study to enable the strategic case to be developed in preparation for a more detailed business case aimed at commercialization.

This study recommends a bold course of action but it is suggested that the climate imperative requires such action to be taken if climate catastrophes are to be mitigated.

The timeframes involved in getting the ball rolling for Bigby in delivering the short-term 2027 opportunities seem a long way off. However, a de-risked investment case informed by diligent engineering, market testing and commercial structuring could very easily take 5 years.

It has been a pleasure engaging with the enthusiasm of the Parish Council and key Stakeholders. The art of the possible is the beginning of the journey, the Bigby Community has a great prospect to embark on a fantastic journey from hereon.



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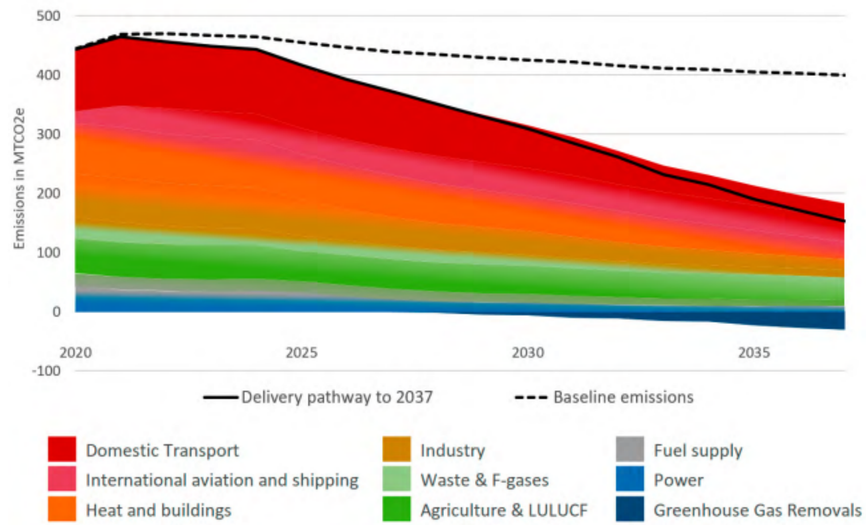
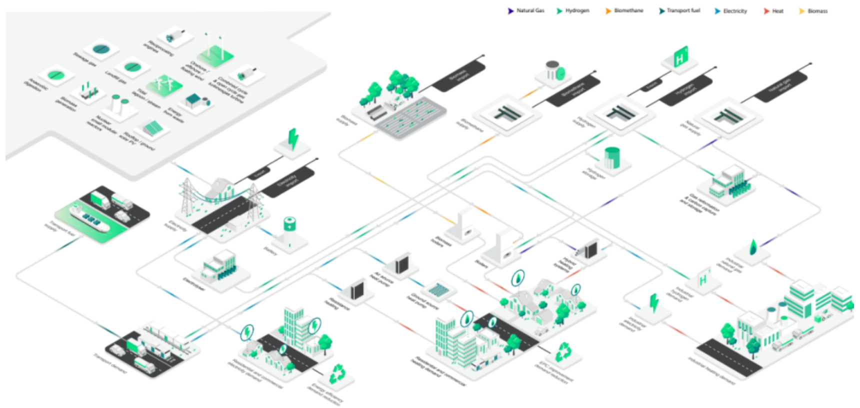
1. Introduction

Introduction & Site Overview
Introduction

- In November 2020, UK government set out a ten point plan for a green industrial revolution. Part of the strategy was to set out a delivery pathway showing indicative emissions reductions across sectors to meet the targets up to the sixth carbon budget (2033-2037).
- In lieu of this national mission, Bigby Parish Council is ideally placed to contribute towards net zero carbon emissions through the development of low carbon energy projects utilising local natural resources whilst creating local job opportunities.
- Local region Bigby and Barnetby have huge geographical potential with close proximity to Humber free port and industrial cluster.
- The Humber Low Carbon Pipelines project forms the backbone of the Net Zero Carbon Humber vision, to enable industries to fuel switch from fossil fuels to low carbon hydrogen. The project will be managed by National Grid. Bigby is on the potential pipeline route envisage by this project.
- We understand that the onsite sustainable energy activity will provide the Bigby Community with a range of advantages including:
  - Provide employment for local people, creating low carbon business solution
  - Reduce transport requirements
  - Be completely sustainable identified within the area as a forward-thinking sustainable energy conscious community
  - Zero waste aligned with sustainability objectives where waste is identified in the form of local inefficiencies of heat generation, power consumption or as residual waste streams from new or existing businesses
  - Zero carbon emitter aligned with being a sustainable energy conscious community where renewable energy provides the transition to being zero carbon
- This report presents a high level assessment of some of the preferred scenarios for the Parish Council to contribute towards net zero carbon emissions and decarbonise energy systems.

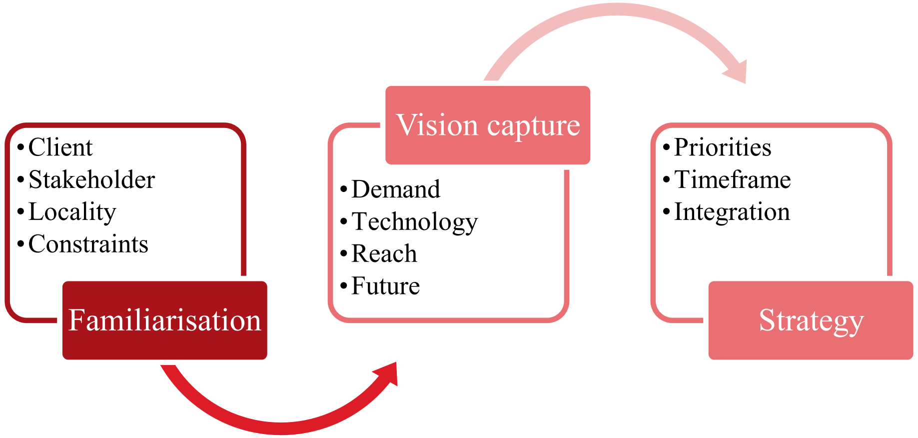


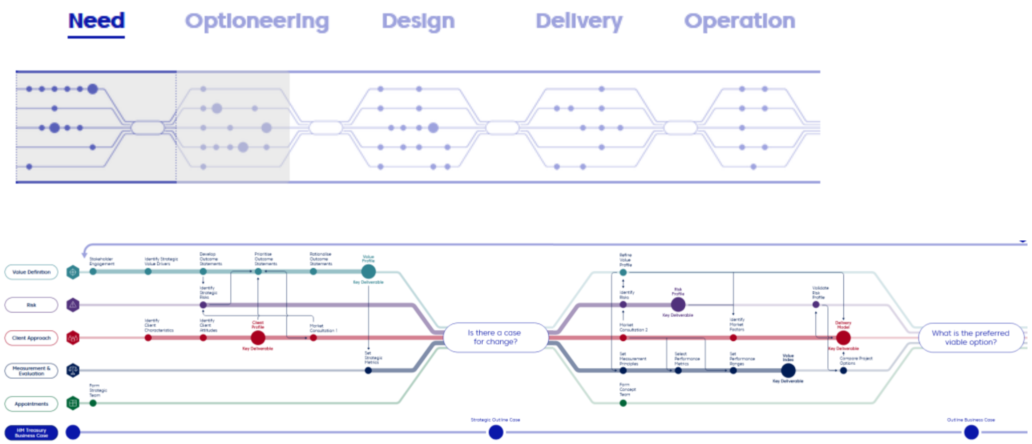
Indicative delivery pathway to 2037 by sector (BEIS Analysis (2021))



Introduction & Site Overview
Study Process

- The process employed in developing the strategy follows three simple steps:
  - Familiarisation with the location, demographic, technical constraints and key stakeholders
  - Capturing a Vision of the renewable/net zero opportunities through appreciation of existing demand, examination of appropriate technologies, developing a view of the wide area reach and examining the phased and future opportunities pathways to pragmatic delivery.
  - Develop the strategic narrative articulating the delivery pathway, identifying priorities, the timeframe and its integration into the development prospectus to the Parish and wider area.
- The process and the formation of the study output is geared towards deliverability, it therefore follows that a series of next steps are key to realising the art of the possible.
- Our process broadly follows the Construction Industry Hub Toolkit recently launched





CONSTRUCTION INNOVATION HUB

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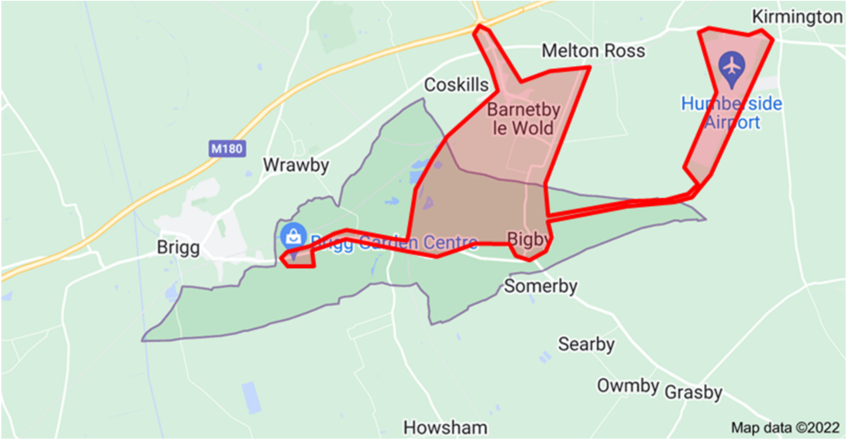
Introduction & Site Overview
Site Overview

Site Overview

- Bigby Parish is in the West Lindsey district of Lincolnshire, England and includes Bigby Village and the hamlets of Kettleby and Kettleby Thorpe as well as a relatively new development of executive homes at Pingley Vale, a former Second World War Prisoner-of-war camp.
- Bigby Village lies on the Viking Way and is situated about 10 miles (20 km) south from the Humber Bridge, and 4 miles (6 km) east from the town of Brigg. All Saints Church, is a Grade 1 listed building which dates back to the 12th century. The village lies in the Lincolnshire Wolds, a designated Area of Outstanding Natural Beauty and close to the administrative border with North Lincolnshire. It comprises of a variety of traditional cottages, manor houses and more modern, mainly executive type, housing.
- Bigby's name comes from an Old Norse personal name 'Bekki' + Old Norse 'býr', meaning "settlement" or "farmstead" and is recorded in the Domesday account as "Bechebi", with the Lord of the manor as William son of Nigel.
- Kettleby (sometimes spelled Kettelby) lies about 1.5 miles (2.4 km) west of Bigby village. The deserted medieval village (DMV) of Kettleby was first recorded in a Domesday records in 1066.
- The Parish is home to a variety of energy using businesses, the largest of which are Kettleby Quarry (Breedon Aggregates) and Brigg Garden Centre, with a diverse range of smaller enterprises, many of which complement the agricultural nature of the area.
- Bigby Parish Council is a proactive organisation which strives to develop the area to benefit all residents and encourage sustainable development. It is constantly seeking new initiatives to enhance the lives of all who live in the area.



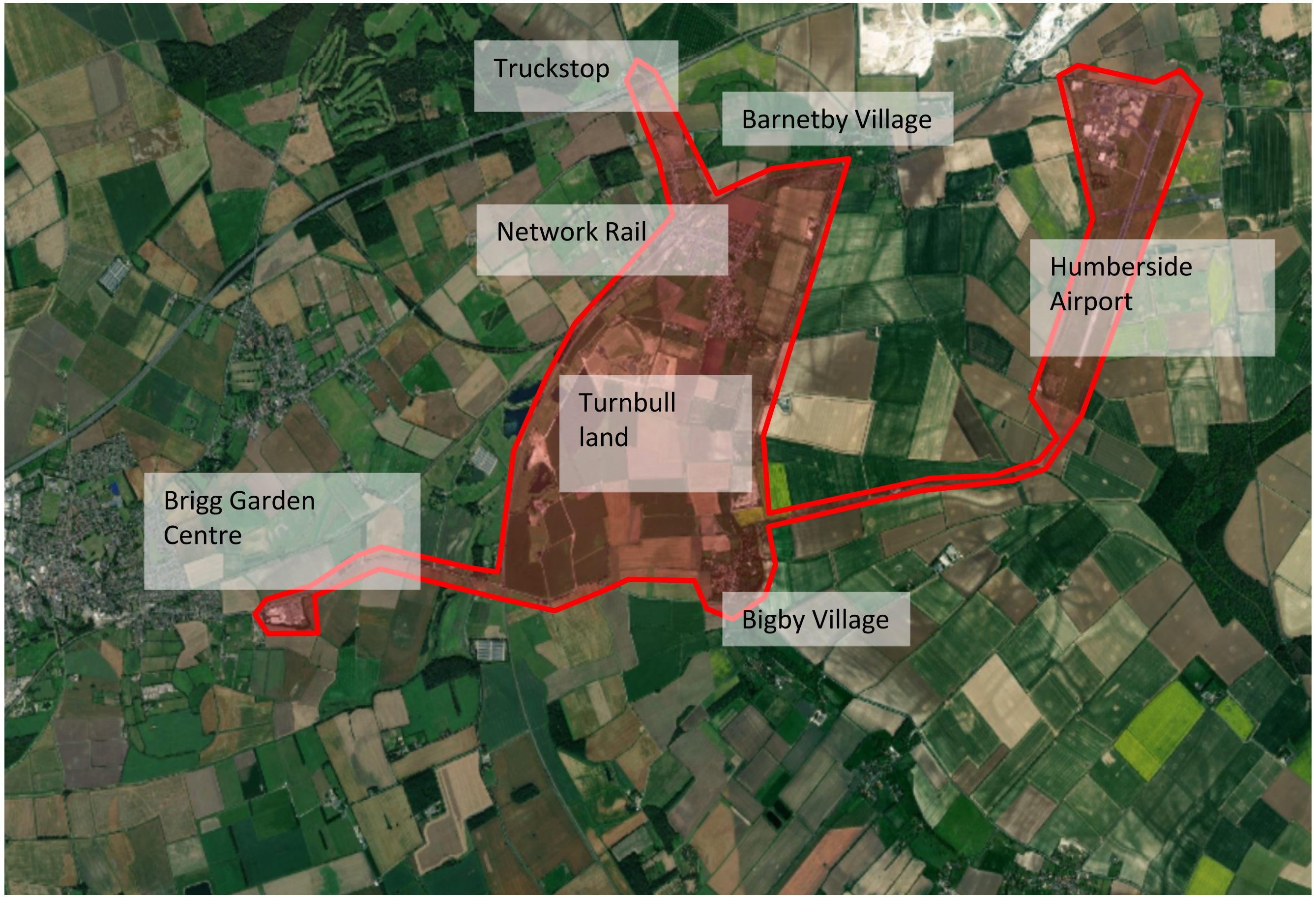
Constraints

- The site has an export only limitation for the generation that can be connected to an existing electrical network, although, there are no constraints on the demand connection. For potential private wire connection, this shall be synchronised with grid intake supply to the consumer subject to the controls not to export back onto the grid.
- However, Northern Powergrid has highlighted to reinforce NGET/132kV Keadby substation that feeds other substations downstream around the area. The anticipated timescale for reinforcement is 2-3 years. This reinforcement is envisaged to allow adequate export back onto the grid.
- Apart from electricity, there are no issues of other utilities around the area including water, gas and telecom. Detailed assessment summary has been attached as an Appendix 1 to this report.

Introduction & Site Overview
Stakeholder Engagement

Establishing stakeholder

- Types of stakeholders identified include:
  - Truck Stop: Brocklesby estate
  - Brigg garden centre
  - Humberside Airport
  - Network rail development.
  - Anthony Turnbull Ltd.
  - JCB (vehicle supplier to farm and aggregate industries)
  - Parish Council
  - Utility companies
  - Melton Ross Quarry (Singleton Birch)
  - Breedon Aggregate



Site Overview

Introduction & Site Overview
Timeframe, Demand and Generation

Strategy Formation

- Arup has defined a timeline for generation and demand around the potential area
    - **Short term:** This is defined as the potential for the development of generation and upcoming demand from **0 to 5 years**
    - **Medium term:** We anticipate the medium term is for the generation technologies and development around the radar in the next **5 to 10 years**
    - **Long term:** With long term, we envisage the integration of multiple technologies with a central focus on the generation and demand of hydrogen as a fuel. This is defined for a timescale from **10 to 15 years.**
- The figure to the right defines timeline along with key generation and demand opportunities that we expect to consider for the strategy build up of the council.

Short Term

- Generation:
    - Solar PV, Onshore Wind, Battery Storage
- Demand:
    - Brigg Garden Centre, Humberside Airport and Business Park, Truck Stop, Village EV Charging, Bigby/Barnetby village ground source heat (electric)

Medium Term

- Generation:
    - Battery Storage, Anerobic Digestion for heat, power and CO2 generation opportunities
- Demand:
    - Glasshouses, Data Centers and Network Rail Development

Long Term

- Generation:
    - Multiple and integrated generation schemes i.e. Solar, Geothermal, AD and battery storage
- Demand:
    - Hydrogen (electricity, truck refueling, alternative fuel for agricultural vehicles)

Timeline for the generation and demand opportunities

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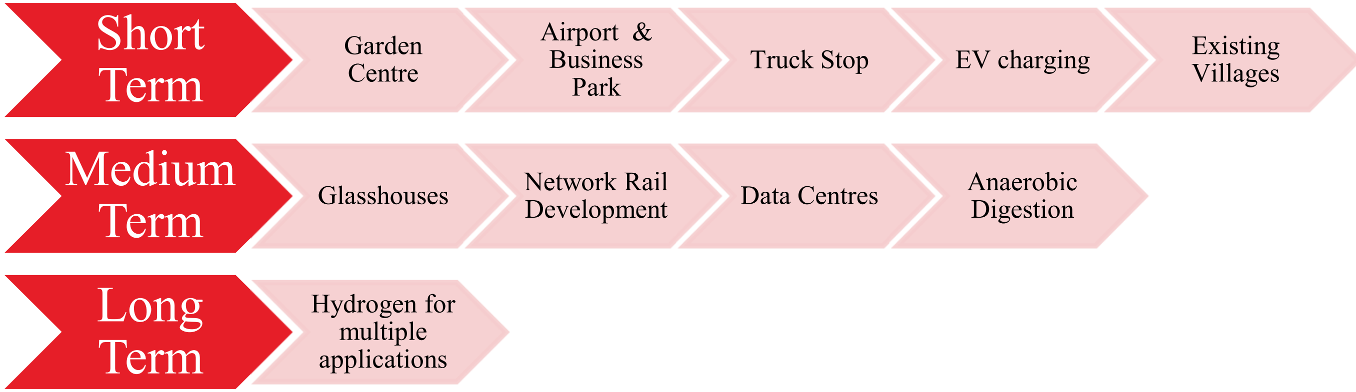
2. Existing & Potential Demand Opportunities

Existing & Potential Demand Opportunities
Demand and Energy Consumption

Sources of demand

- We have assessed and analyzed the current and future demand scenarios around the area and concluded various potentials as highlighted in the figure to the right.
- We anticipate that most immediate demand in the **short run** includes Bigby/Barnetby village ground source heat demand, existing garden centre electric demand, Humberside Airport electric demand, truck stop electric demand and potential EV charging demand.
- For the **medium term**, there will be both electric and heat demand at glasshouses and network rail development. For data centres, there will be both electric and cooling demand. It is anticipated that the amount of heat at data centers could be captured and utilized at glasshouses. Anaerobic digestion represents a demand for energy crop and animal waste with resulting production of residual products and accompanying methane rich fuel.
- Detailed feasibility of opportunities would be assessed in the next steps.
- The **long-term** demand is heavily influenced by evolving hydrogen market. The hydrogen could be required by the Humberside Airport, heavy vehicle fueling and further electricity generation via fuel cells.



Demand Potentials

Existing Demand Opportunities
Demand and Energy Consumption

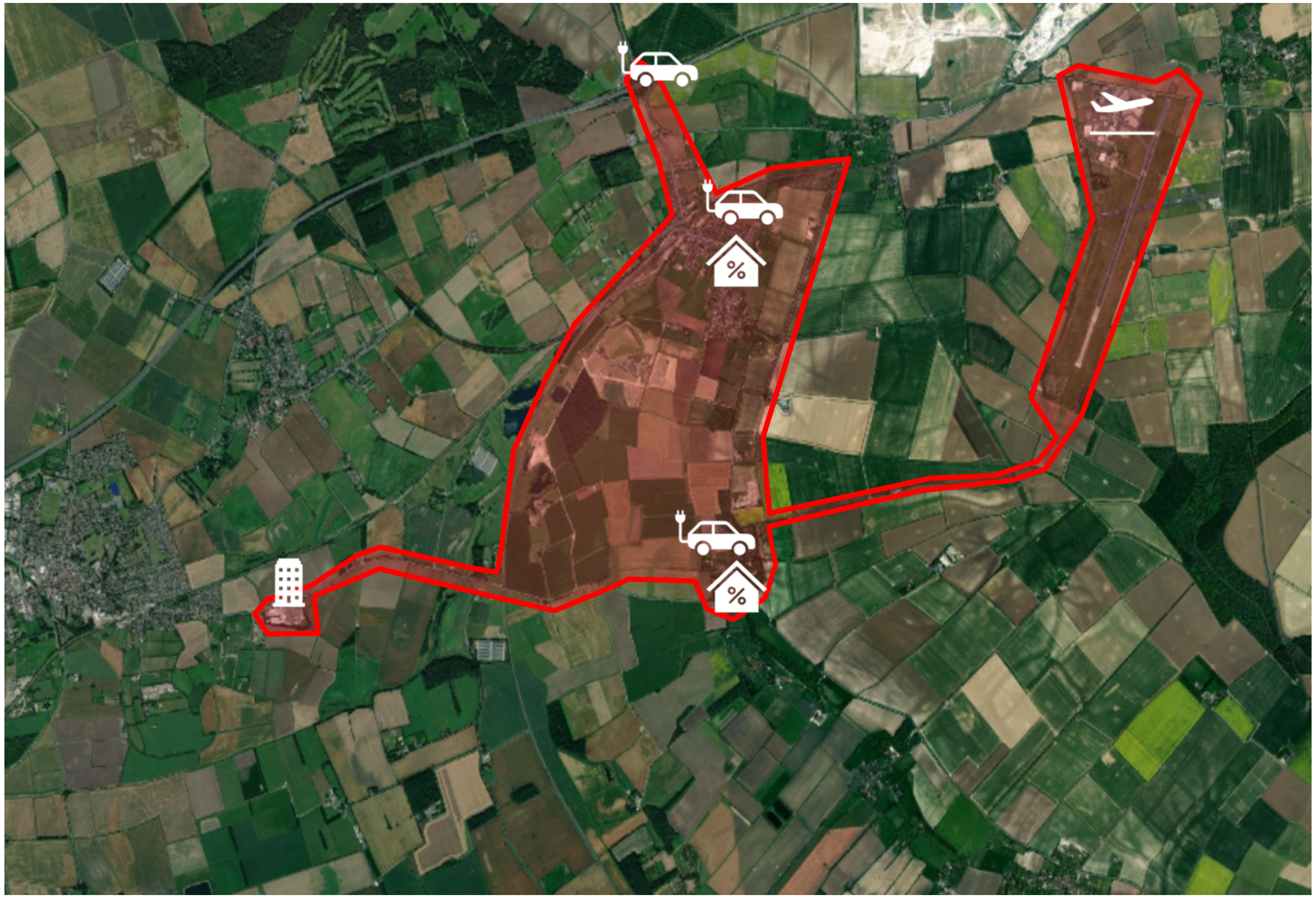
Existing Electrical and Electric Thermal Demand

Electrical demand

- Village EV charging & Truck Stop
- Brigg Garden Centre
- Humberside Airport

Thermal demand

- Barnetby and Bigby Villages

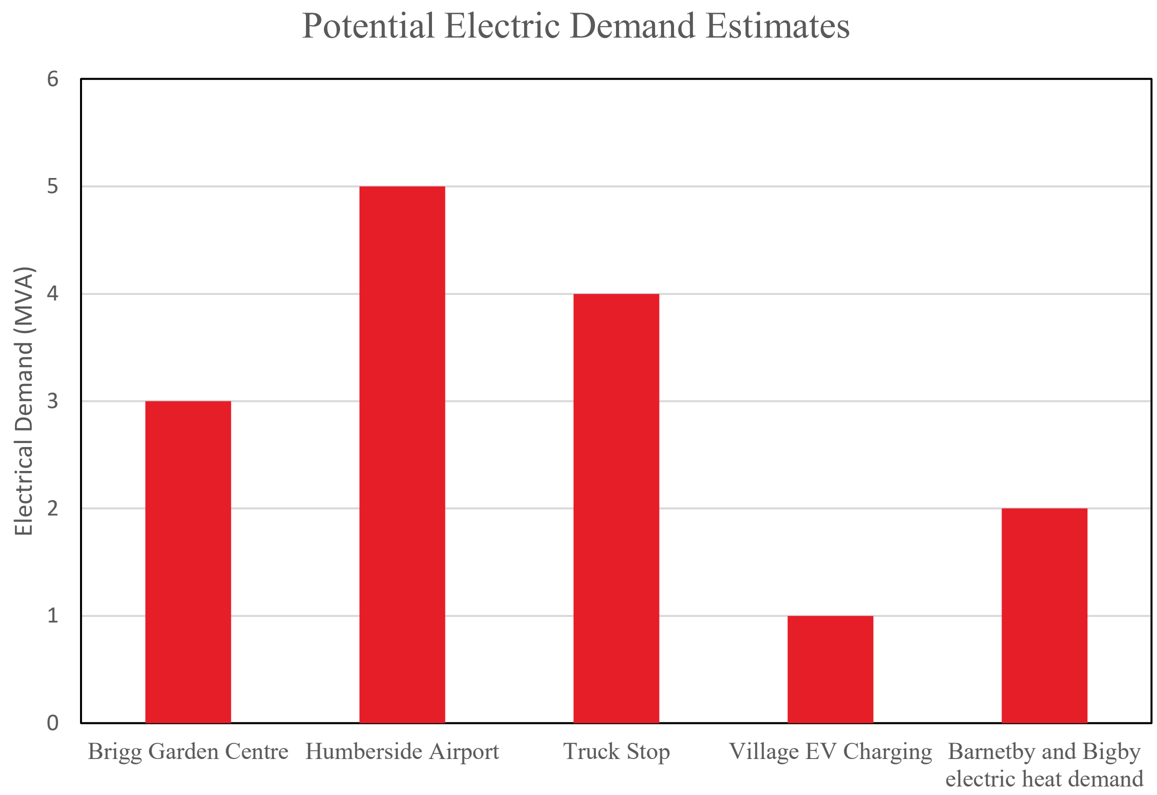


Existing Demand Opportunities

Existing Demand Opportunities
Demand and Energy Consumption

Existing Electrical and Electric Heat Demand

- We understand the importance to estimate the existing demand to fully comprehend the extend of the potential of the whole site and evaluate multiple scenarios.
- Arup has performed the existing demand assessment for the site to overlap with a potential generation scheme development.
- We have established and estimated demands by engagement with key stakeholders, we anticipate these represent an immediate demand realizable in the near future and would fall into the **short term (0-5 years)** pathway.



Short-term existing electric demand estimation

Potential New Demand Opportunities
Demand and Energy Consumption

Potential Electrical and Electric Heat Demand

Electrical demand

- Hydrogen production for local injection, storage or heavy vehicle transportation (5MVA)
- Enterprise Data Centre development (10-12MVA)
- Horticulture glasshouse development (3MVA)
- Network Rail Logistics Centre development (3MVA)
- Anaerobic Digestion

Thermal demand (electric heat demand)

- Enterprise Data Centre development
- Horticulture glasshouse development
- Network Rail Logistics Centre development

Potential medium term (5-10 years) and long term (10-15 years) Demand Opportunities

Potential Demand Growth Opportunities
Data Centre

- For a typical data centre with an IT capacity in the range between 10 and 20 MW, the site footprint could. reach up to the magnitude of 22,000 m^2 (e.g, as seen in the picture on the right hand side, the site footprint is approximately 120 m by 180 m).
- The footprint of a data centre heavily depends on the facility's design, such as building height, cooling technologies, car park requirement, auxiliary services required, office space needed, storage space needed, electricity supply plan, and emergency services access, among others.

Generation, Source & Network Opportunities:

- The IT load density based on floor area is typically in the range between 1.5 and 2 kW per square metres. In addition to the IT load, cooling and other required auxiliary services would increase the total demand of the facility. A typical factor between 1.3 and 1.6 can be assumed. For example, a facility with 1 MW of IT load would require a total power supply from 1.3 to 1.6 MW. This factor is mainly driven by the cooling technology applied at the data centre.
- We anticipate that the development of data centre will fall into a **medium term** projection for the council.

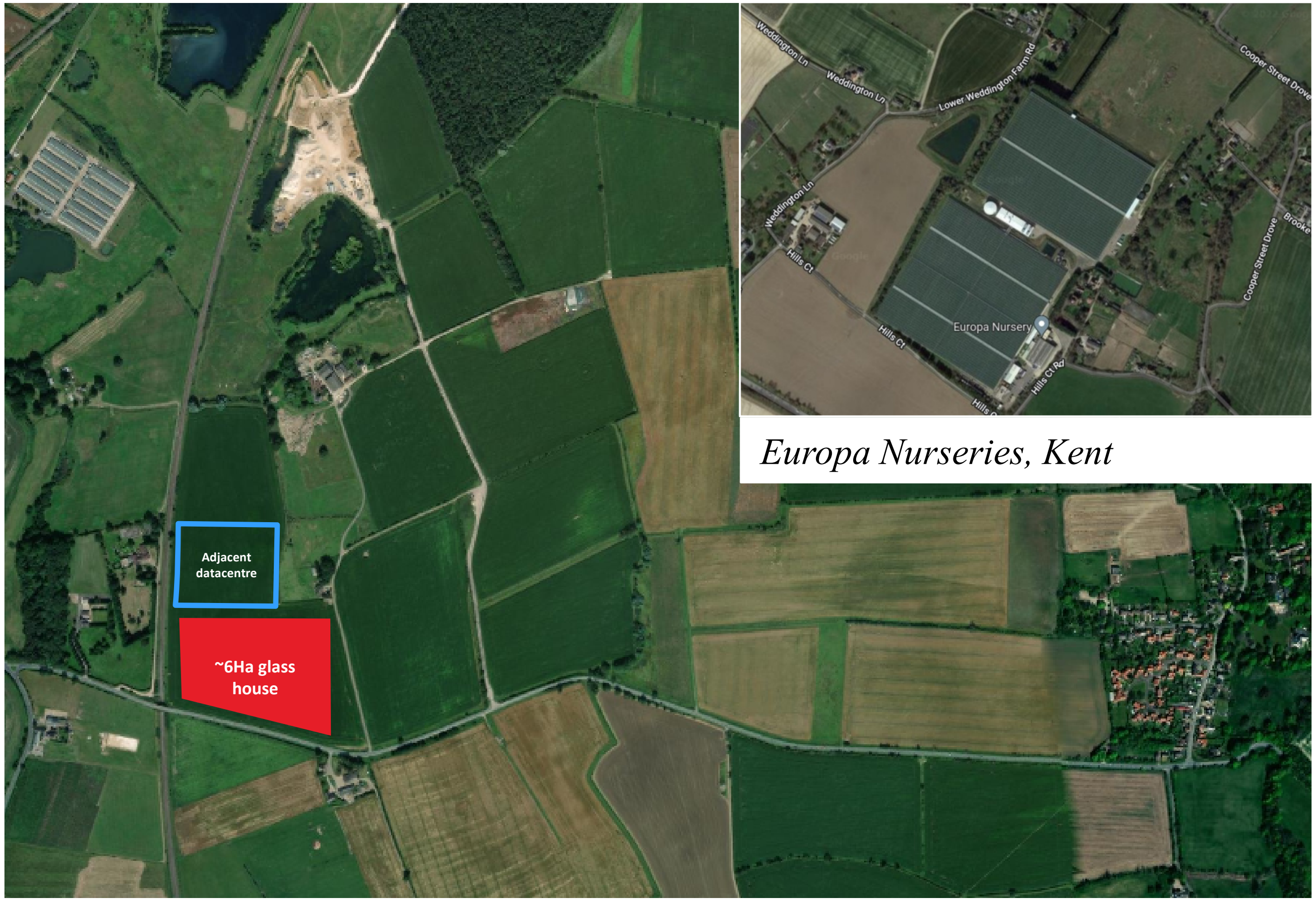
Typical Data Centre Footprint

Potential Demand Growth Opportunities
Horticultural Glasshouse Assessment

- Assume 1.5MW electric per hectare-Ha (10,000m^2) of glass. Supplied via PV/Wind, with battery storage.
- CO2 requirements for yield is an additional requirement. Could be generated via AD reciprocating engine exhaust capture and in future by Humber CCUS CO2 pipeline.
- Estimated heat demand ~3.0MW could be supplied from GSHP/Water source and supplemented via data centre heat recovery. Thermal storage is anticipated for operational flexibility of heat supply and demand.
- Horticulture prospect could be augmented by aquaponics to increase the circularity of fertility.
- We anticipate that the development of horticulture glasshouses will fall into a **medium term** projection for the council.

Generation, Source & Network Opportunities:

- 4 Ha of horticultural glass house would require ~ 6MWe of electrical supply for lighting and power.
- Estimated thermal demand ~12MWe for high-yield crops.



Europa Nurseries, Kent

Potential Demand Growth Opportunities
Network Rail Assessment

- Plot measures area of 60,000m^2 total.
- Assumed on plot two storey building plot of 30,000m^2 floor plate, total services floor area 60,000m^2.
- Assumed thermal energy requirement for a standard air-conditioned office built to future high energy performance standards of 50-100kWh/m^2 (factored CIBSE), the estimated annual thermal energy consumption would be ~4,5000,000 kWh/year.
- Assumed electrical energy requirement of 100-200kWh/m^2 (factored CIBSE), the estimated annual thermal energy consumption is ~9,000,000 kWh/year.
- Assuming a 24/7/365 operation, an average thermal demand will be ~500kW and peak energy demand ~1000kW. Electrical average demand might be ~1000kWe and peak ~2000kWe.
- We anticipate that the network rail development will fall into a **medium term** projection for the council.

Generation, Source & Network Opportunities:

- Sale of renewable electricity via private wire from the generation capacities identified.
- Sale of Ground/Water sourced ambient heat piped to NR localised heat pump(s).

Potential Demand Growth Opportunities
Hydrogen Production Assessment

Arup completed a high-level analysis of the potential for a hydrogen production and storage facility on the site. The analysis assumed that electricity generated from renewable sources on site would supply a 5 MW PEM electrolyser, subsequently, producing 2,200 kg of green hydrogen, daily.

The analysis assessed two facility options:

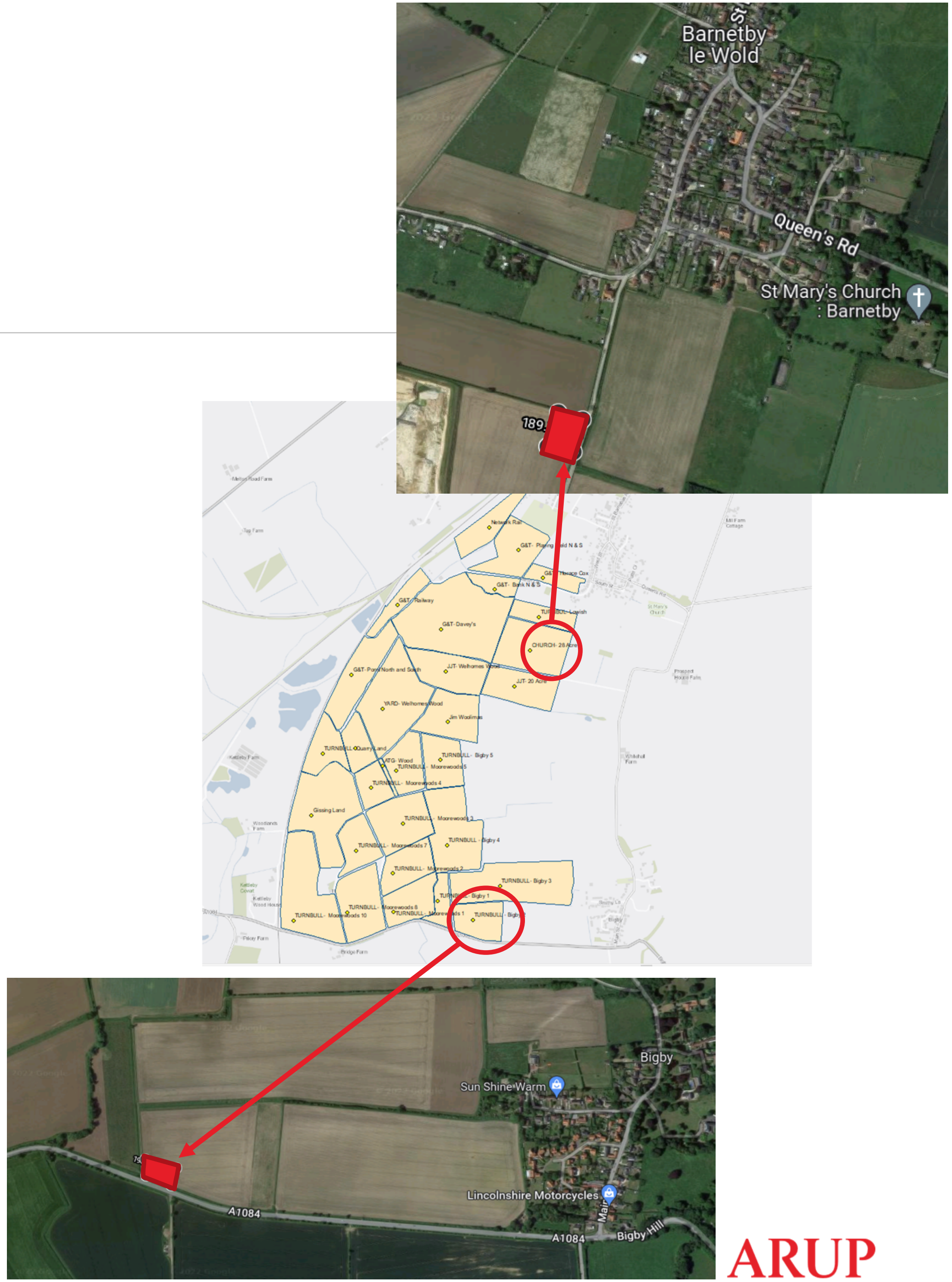
1. Hydrogen production facility
2. Hydrogen production and storage facility (including 5 days of on-site Hydrogen Container Storage)

A summary of the site footprint is documented in the table below for both options.

Option	Footprint (m^2)
1	2,000
2	4,200

There is potential for hydrogen demand from the airport. The hydrogen facility could be situated in the east of the land parcels, close to the airport or in the south, next to the A1084 to allow easy site access for the transportation of hydrogen via roads. The adjacent figure illustrates example hydrogen production and storage facility locations. At this stage, we have briefly considered the production of ammonia from hydrogen but ruled out of the exercise.

We anticipate that the hydrogen production facility will fall into a **long-term** projection for the council.



Hydrogen Production Facility

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3. Generation, Source & Network Opportunities

Generation, Source & Network Opportunities
Energy Generation, Sources & Networks

Types of energy generation technology and sources considered

- Arup has evaluated the potential of diverse sources of technology for the generation of both heat and electricity.
- The sources to meet electricity demand for diverse applications include:
  - Solar PV
    - Solar PV is the fastest growing technology in the UK recently with a short construction timeframe and quick return on investment. As of June 2021, installed capacity is around 13.5GW in UK. The capacity factor of solar PV is around 10%.
  - Onshore Wind
    - In UK, wind power is the most matured renewable technology with one of the best resources in the world. As of March 2022, UK has over 24.6GW of wind generation. The capacity factor of onshore wind farm is around 30-40%
  - Battery Storage
    - Battery storage is gaining excessive momentum in the UK especially due to its diverse grid balancing services in addition to peak shaving co-located with intermittent renewable energy sources
  - Private wire
    - Private wire is an alternative to grid connection, which will directly feed the electricity generated to a large potential consumer, particularly at a price less than the retail price of electricity.
  - Anaerobic Digestion (AD)
    - AD is a mechanism to utilise the food stocks, biodegradable materials and microorganism to produce electricity.

- In order to meet heat demand, different sources of thermal generation include:
  - Ground Source Heat: Extracting heat from an underground source via boreholes
  - Water Source Heat: Extracting heat from a nearby water source such as lakes, ponds or water bodies
  - Geothermal Resource: Extracting heat via two boreholes (abstraction and discharge). The extracted heat could be utilised for heating purpose via heat pumps or electricity generation purpose via Organic Rankine Cycle

Generation, Source & Network Opportunities
Solar PV Assessment

- Arup has assessed the viability of the solar PV across the parcels of land.
- For the PV scheme we have:
    - Assess the most suitable long-term solar irradiance data set source.
    - Define project-specific loss and uncertainty assumptions such as reflection losses, irradiance level losses, shading losses, soiling losses, DC cabling losses, inverter losses, AC cabling losses and transformer losses.
    - Model solar resource and energy yield analysis utilising PVSyst.
        - The software package PVSyst has access to a wide range of PV module and inverter specifications and is compatible with weather data from a range of sources.
- During the analysis, we have split the areas and individually assess the potential of each in terms of maximum installed capacity and annual energy yield. The overall area suitable for the PV arrays is approx. 814,000 m2 (81.4 hectares).
- With 25 degrees south facing, inter-row spacing of 2.5m and panel ratings of 455Wp, the maximum installed capacity of the areas is of the order of 75MWac with an annual energy yield of 78MWh.
- The capital costs for the ground mounted solar PV is around £500/kWh to £530/kWh with an operational costs of £6/kW/year.
- The flexibility around the PV installation provides an opportunity to install during **short term** to **medium term** scale of development.

Solar PV Layout

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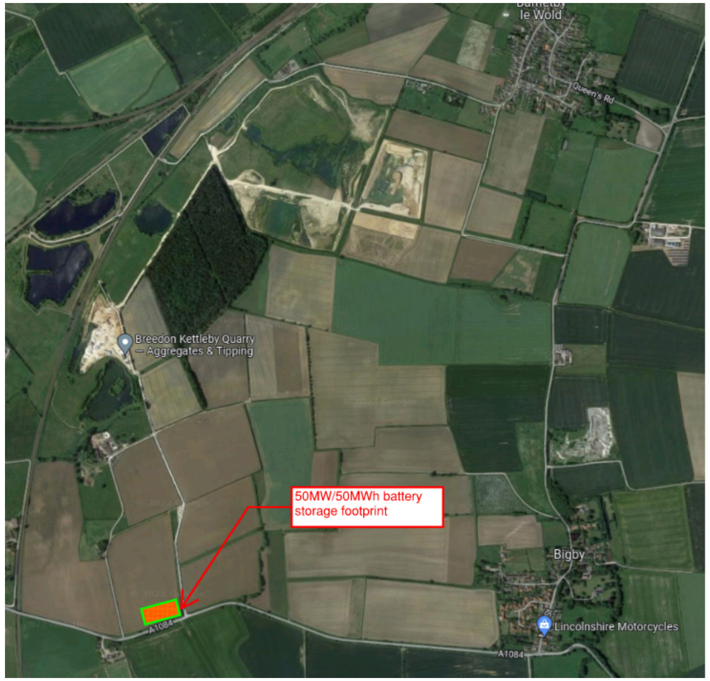
Generation, Source & Network Opportunities
Battery Storage Assessment

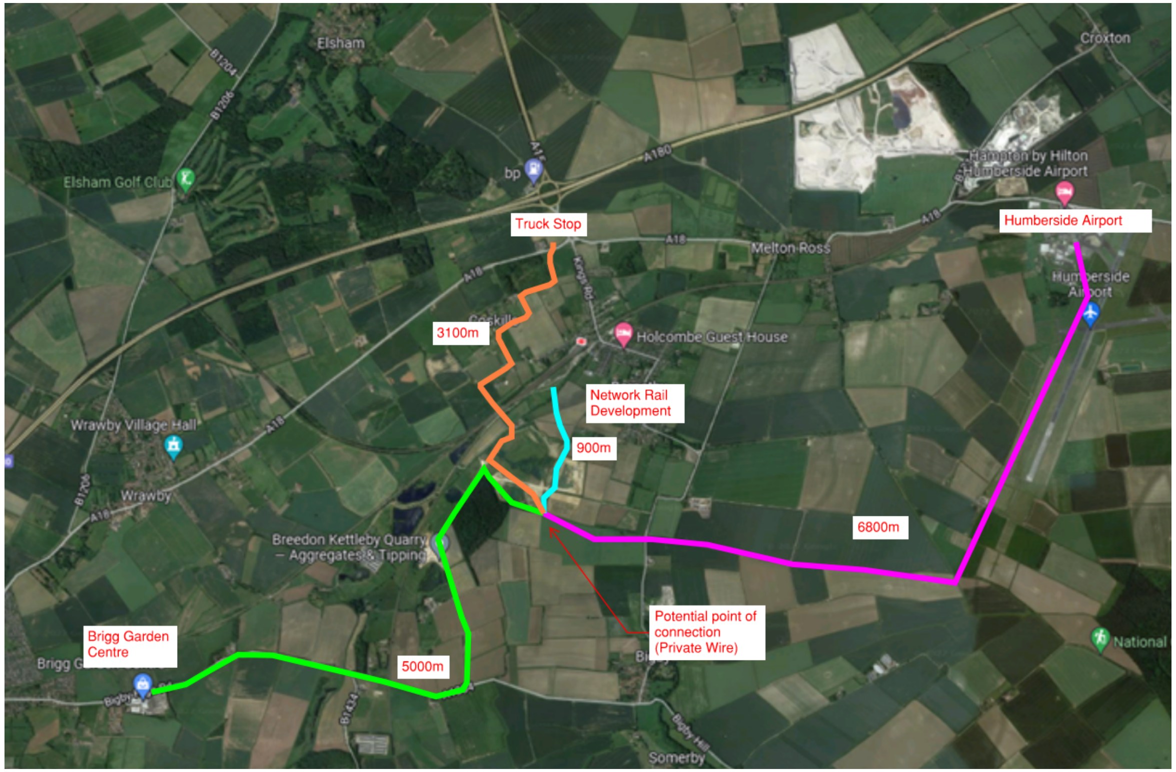
- Arup has assessed the feasibility of co-locating battery storage with solar PV and/or onshore wind to provide electricity during the period of no sunshine and wind and consequently to maximise the energy generation from intermittent sources of generation.
- The Battery Energy Storage System (BESS) consists of a containerised battery energy storage units each housing the battery modules, racks, power distribution and conversion systems, HVAC and fire suppression systems.
  - The battery modules will be supplied by the manufacturer and installed in racks typically comprised of 14 modules (in a IP308S configuration) with a capacity of 113.34 kWh.
  - There are between 34 and 35 battery racks per battery storage container with a total energy capacity of between 3.74 MWh or 3.85 MWh.
- Each battery storage container is connected to a Power Conversion System (PCS) or inverter to covert the DC voltage generated by a battery modules to AC for distribution.
- Each transformer shall be connected to the two inverter/containers, which will increase the AC output (690V) of the inverters to 11kV for distribution on and off site.
- A typical footprint of 50MW/50MWh BESS is 4,000m2 including balance of plant. A typical arrangement of 50MW/50MWh BESS is highlighted in the figure to the right.
- The flexibility around the battery storage provides an opportunity to install during **short term** to **medium term** scale of development.



BESS system

Generation, Source & Network Opportunities
Private Wire Assessment

- We understand that the spare capacity (generation export limitation) at a local grid network is negligible. Therefore, we have assessed an alternative way to feed generated electricity to nearby large commercial consumers.
- For potential private wire connection, this shall be synchronised with grid intake supply to the consumer subject to the controls not to export back onto the grid.
- We have identified atleast three potential offtakers of generated electricity either from solar PV, onshore wind, and/or AD plant co-located with battery storage.
- These three potential consumers are:
  - Humberside Airport
  - Brigg Garden Centre
  - Network Rail Development
  - Truck Stop
- The potential private wire routes and distances are highlighted in the figure to the right.
- The proposal for the council would be to consider Private Wire connection to the interested offtakers from day 1 as it may not require to reinforce the existing grid infrastructure. Additionally, it would be beneficial for both investors, who will sell electricity to pay off their capital costs, and consumers, who would end up buying electricity from the investors/third party at a price less than the retail price of electricity.



Private Wire Connection

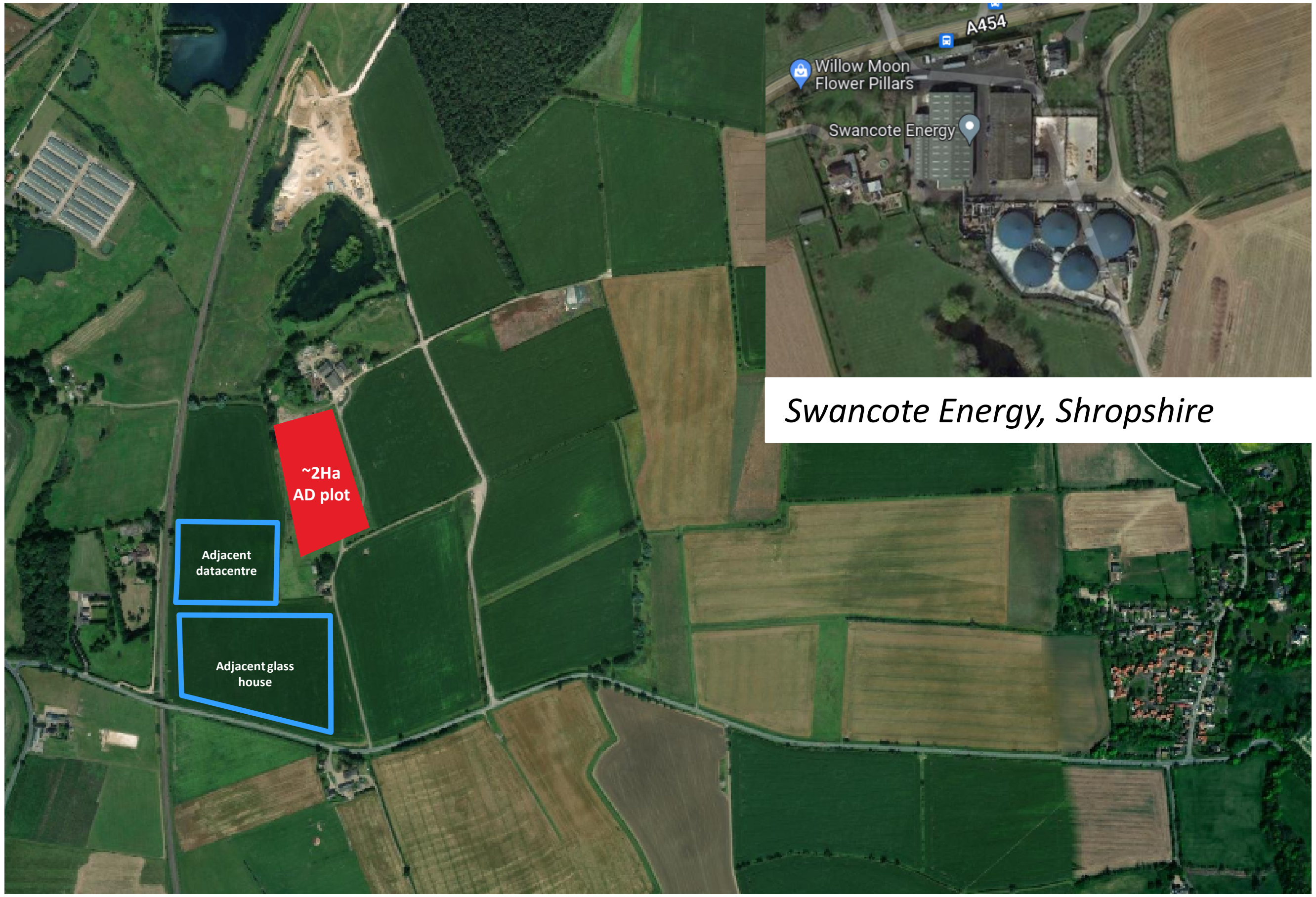
Generation, Source & Network Opportunities
Onshore Wind Assessment

- The Bigby area has a considerable amount of wind resource, with mean annual wind speeds of 7.53 m/s and 8.69 m/s at 50 m and 100 m hub heights respectively, and the dominant wind direction is the south west. Consequently, the feasibility of a wind farm to supply electricity to the local network has been assessed.
- To consider the placement locations of wind turbines the following criteria were considered:
  - Distance to nearby roads and habitats
  - Wind directions
  - Spacing between wind turbines.
- The size of the chosen wind turbine is 3.45 MW with a hub height of 85 m and 120 m rotor diameter. The high level assessment show the possibility to install up to 5 wind turbines in the available land. The land between turbines can be used as normal with minimal impact on land usage.
- The estimated capacity factor for the selected turbines and layout is 32%. This translates to an annual yield of 9,671 MWh per turbine.
- However, there are constraints around the proximity to the Humberside airport and visual impact to the customers around the area, which makes it challenging to implement and install wind turbines as part of the energy strategy.

Potential onshore wind

Generation, Source & Network Opportunities
Anaerobic Digestion Assessment

- A 4Ha plant area handling 75k Tonnes / year of mixed food waste and agricultural feedstock such as Swancote Energy (pictured) generates ~2MWe of electricity, with ~50% going to parasitic demand.
- Pro-rata for a 12k Tonne / year fuel crop such as locally grown Maise on brownfield land, electricity production would be ~0.33MWe before parasitic demand. Land take required would be ~2Ha.
- Without food and other AD suitable bio-waste streams, which can attract waste disposal revenues supplementing the local fuel crop, the land and generating capacities economies of scale will not be realised and unlikely to be viable.
- However, an added value outcome to improve viability could be achieved by the generation of CO_2 and heat from the combustion of AD derived methane for use in horticultural glasshouse business/demand development.
- The AD installation envisage to provide baseload generation along with other source of renewable generation. It also provides an opportunity to install during **short term** to **medium term** scale of development.

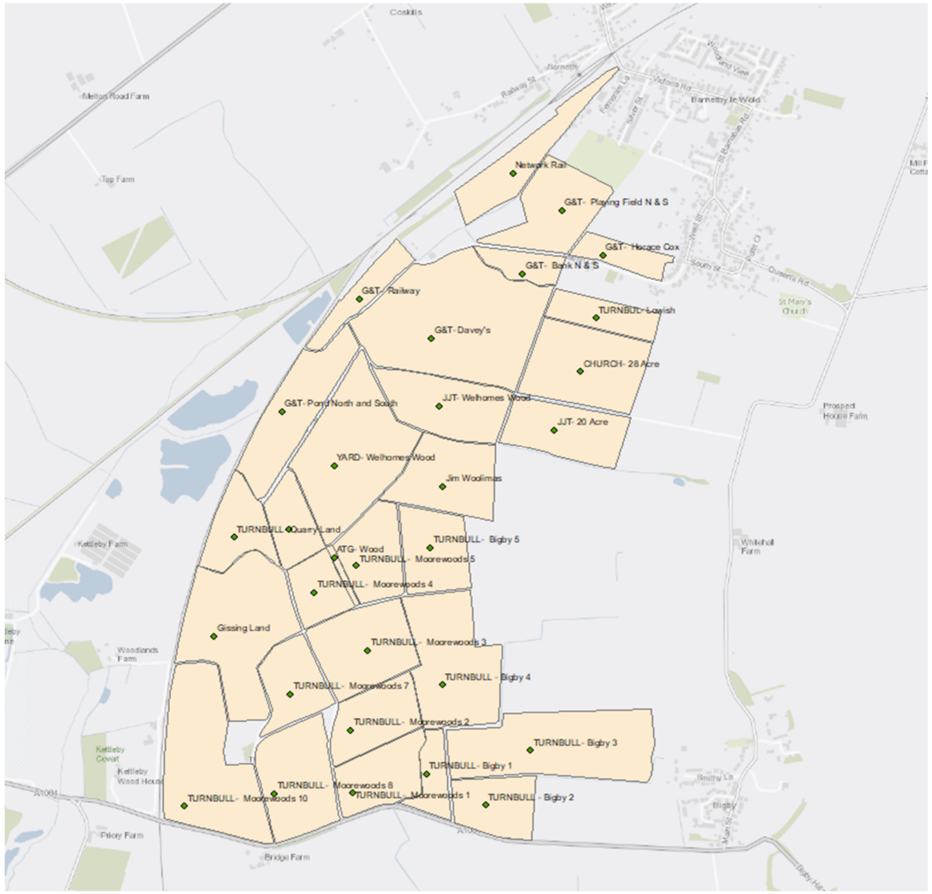


Potential AD Plant

Generation, Source & Network Opportunities
Thermal Energy Assessment

Geothermal and water source potential

- Geothermal assessment and usage to glasshouse and network rail.
- Aquifers or water supply to H2 production and water source heat pumps to capture thermal energy.
- Quantify thermal heat demand for network rail
- Bigby villages, approximate heat density, indication of ground or water supply
- Brigg garden centre opportunities
- https://www.cambridgeshire.gov.uk/residents/climate-change-energy-and-environment/climate-change-action/low-carbon-energy/community-heating/swaffham-prior-heat-network
- Swaffham Prior Heat Network
- village of Swaffham Prior to reduce their reliance on oil heating and transfer to a thermal energy heat network - find out more



Site Overview

Generation, Source & Network Opportunities
Geothermal Assessment

The geology is generally low permeability and therefore not conducive for a shallow open loop GSHP

Geology

A summary of the geological conditions beneath the site is presented in the table below.

Geology	Depth to base (mbgl)	Depth to base (mOD)	Description
Ancholme Group mudstones	200	-185	Grey marine and silty mudstones with lenses of limestones
Redbourne Group	270	-255	Sandstones and limestones
Coleby Mudstones	350	-335	Medium and dark mudstone and siltstone,
Scunthorpe Mudstones	450	-435	Grey, calcareous and silty mudstone with thin beds of limestone and siltstone
Mercia Mudstone Group	725	-710	Red mudstones and siltstones with beds of sandstone, gypsum/anhydrite and halite-bearing units
Sherwood Sandstone Group	1025	-1010	Red, yellow and brown sandstone

Hydrogeology

Within the site area the geology is not sufficiently permeable within the uppermost 1km for an open loop GSHP system. Therefore traditional open loop options are considered unlikely to be feasible.

However, the Sherwood Sandstone Group is present at around 1km depth. This is a highly productive aquifer and is used for water supply elsewhere in the UK and is the aquifer used for geothermal district heating in Southampton. There is limited data on the permeability of the Sherwood Sandstone beneath Bigby however it is likely that at 1km groundwater flow is via fractures rather than intergranular flow.

Heat

The inferred temperature profile depth beneath the site based on BGS data is presented below:

- 16°C at 100mbgl
- 18°C at 200mbgl
- 28°C at 500mbgl
- 34°C at 1000mbgl
- 170°C at 7000mbgl.

Based on this data the geothermal gradient is estimated to be around 24°C per km depth in the uppermost 1km, which is lower than the UK average.

Generation, Source & Network Opportunities
Geothermal Energy Assessment

Closed loop options possible at the site include closed loop boreholes (200m deep). These systems provide stable baseload thermal energy but may require large footprints.

Ground energy options

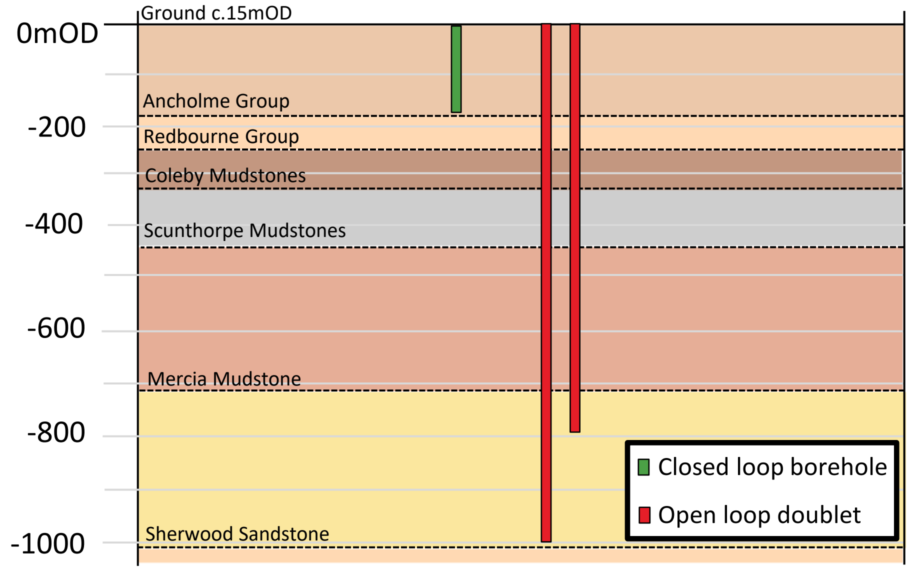
The table below provides an initial assessment of the ground energy options that are most likely to be suitable for the ground conditons at the site.

Geology	Depth to base (mbgl)	Initial ground energy options appraisal (colours represented on cross section)
Ancholme Group mudstones	200	**Closed loop boreholes**
Redbourne Group	270	Unlikely to be feasible
Coleby Mudstones	350	Unlikely to be feasible
Scunthorpe Mudstones	450	Unlikely to be feasible
Mercia Mudstone Group	725	Unlikely to be feasible
Sherwood Sandstone Group	1025	**Deep geothermal open loop doublet**

Closed loop borehles

Closed loop borehole systems involve the installation of tubing into boreholes which usually range between 50 and 200mbgl.

For this project we have assumed boreholes to 200mbgl with a typical spacing of 8m (more closely spaced boreholes will increase the potential for thermal interferance between boreholes). Based on a thermal conductivity of 40W/m, one 200m deep borehole can provide 8kWth thermal energy from the ground. At 200m the temperature into the heat pump is expected to be around 18^{o}C.



Preliminary ground model showing closed loop and deep geothermal options

Generation, Source & Network Opportunities
Geothermal

A single deep open loop doublet may provide around 1-2 MW thermal energy from the ground.

Deep geothermal doublet

A deep open loop doublet involves two boreholes, one for abstraction and another for discharge. To reduce the potential for thermal interference the boreholes are seperated as far as practicable and seperated vertically. A deeper borehole is used for abstraction and a shallower borehole for discharge of the cooler geothermal brine once it has passed through a heat exchanger.

Unlike shallow open loop systems which are typically 50 to 150m deep, the geology of the site would require a borehole of approximately 1000m to reach the base of the Sherwood Sandstone aquifer, and a second borehole of approximately 800m for reinjection, increasing drilling costs and pumping costs signigicantly.

At this depth, flow rates of the Sherwood Sandstone Group are unknown which carries the risk of not achieving the yield required. A yield of approximately 40 l/s and ΔT of 10^{o}C would provide 1.6 MWth of heat from the ground to the heat exchanger, at a temperature of around 34^{o}C. The Sherwood Sandstone is a very permeable aquifer and this method has been successfully implemented to generate 2MWth of energy from the ground in Southampton.

For wells up to 1000m depth, a mobile drilling rig might be suitable to drill the boreholes which would require an area of 0.25 ha during drilling. Use of a mobile drilling rig would significantly reduce the drilling cost when compared to other deep geothermal projects which require a "fixed" drilling rig, occupying a much larger footprint during drilling and requires additional equipment and possibly enabling works.

Once complete the footprint of the boreholes would be very small, similar in size to a manhole.

Surface water

There are several ponds/ small lakes within the site which could be used for an open or closed loop surface water source heat pump (SWSHP) system.

Surface water temperatures generally vary less than air but more than the ground. Tempeartues are generally lower than the ground, particularly when compared to the closed loop borehole systems assesseed for this project. Temperatures are generlaly lower in winter months, particularly for smaller static water bodies such as the ponds/ lakes at the site. Furthermore, the water level within surface water bodies can vary seasonally.

Due to the small scale of the ponds on the site, and in particular the unknown depth of the ponds, a SWSHP utilising these features will need to be carefully designed to minimise the risks of overheating/ overcooling. An open loop system will need to be consider falls in water levels as part of the pump design.

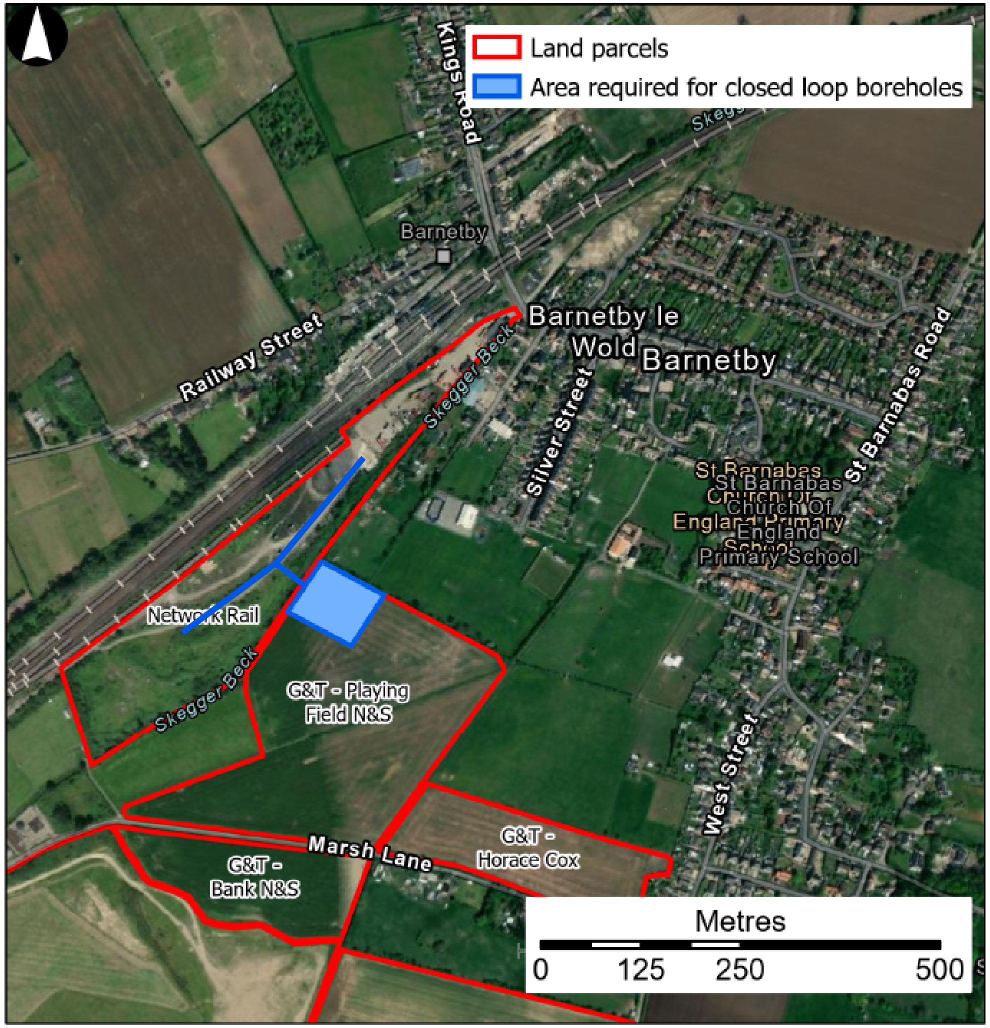
Further data on the size of the ponds/ lakes, seasonal changes in water levels and temperatures will be required to determine the thermal capacity of the ponds/ lakes. However, there is potential to utilise these features, possibly in combination with GSHP, to help meet the site building heating/ cooling demands.

Generation, Source & Network Opportunities
Geothermal

Geothermal potential at Network Rail

Closed loop GSHP

- Based on an assumed two storey building plot of 30,000m^2 (60,000m^2 total), and an assumed thermal energy requirement for a standard air-conditioned office built to high energy performance standards of 50-100kWh/m2 (CIBSE), the estimated annual thermal energy consumption is 4,5000,000 kWh/year.
- Assuming a 24/7/365 operation, a peak energy demand of 1000kW has been assumed.
- Based on an energy yield from the ground of 8kW, 125 closed loop boreholes will be required to meet this demand.
- These boreholes would require an area of 6,600m^2 (0.7 ha) – indicated on the figure opposite.
- The area indicated on the figure does not take into account existing buried features and an assessment of utilities would be required.



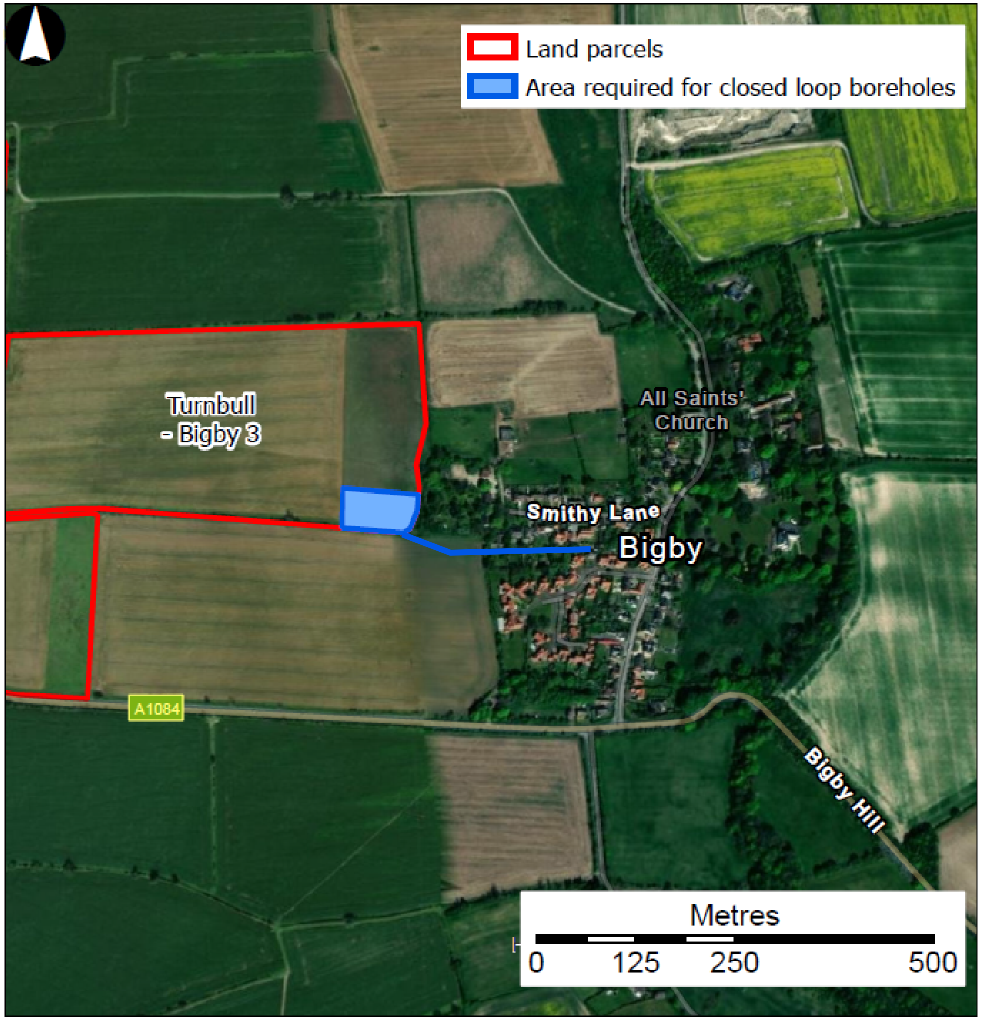
Possible area for a closed loop array to heat the Network Rail compound

Generation, Source & Network Opportunities
Geothermal

Geothermal potential at Bigby village

Closed loop GSHP

- With 100 homes, Bigby village has a peak demand of 700 kW.
- Based on an energy yield from the ground of 8kW, 88 closed loop boreholes will be required to meet this demand.
- These boreholes would require an area of 4,500m^2 (0.45 ha) – indicated on the figure opposite.
- The area indicated on the figure does not take into account existing buried features and an assessment of utilities would be required.



Possible area for a closed loop array to heat the homes in Bigby

Generation, Source & Network Opportunities
Geothermal

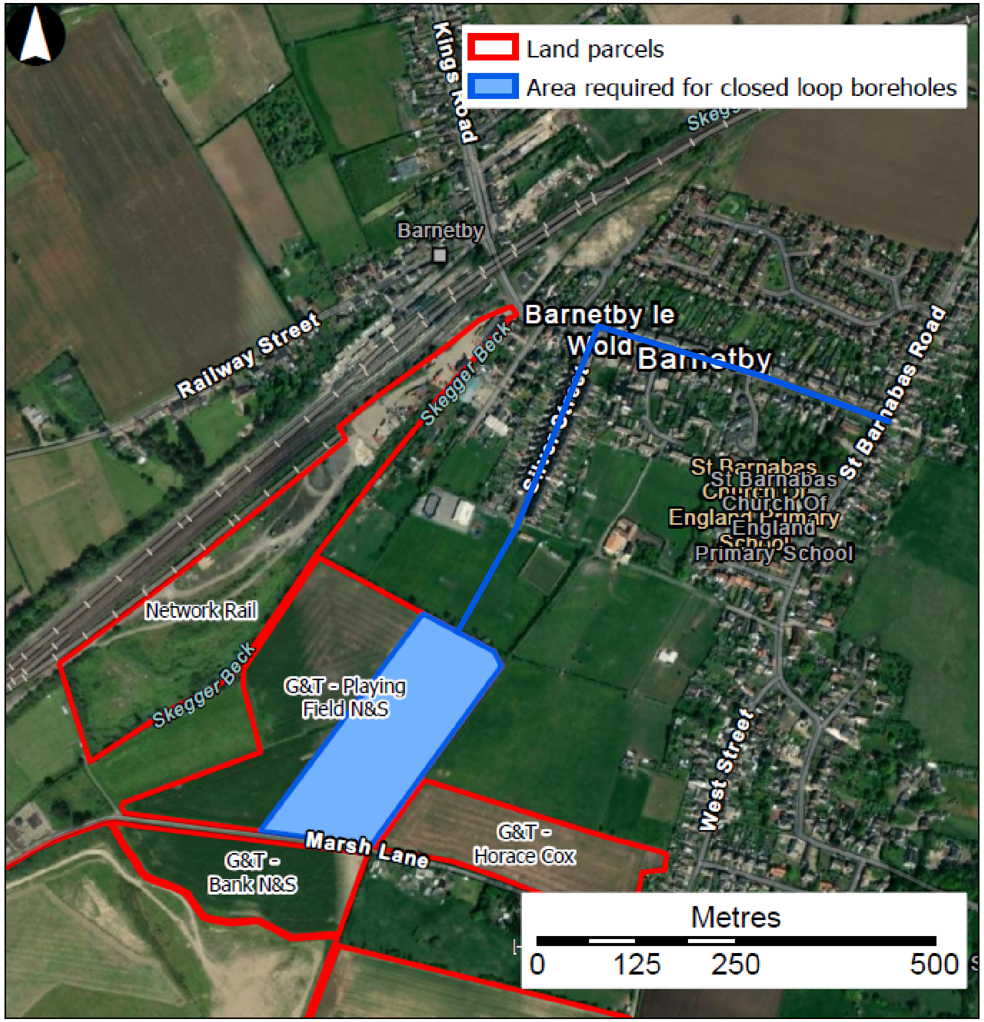
Geothermal potential at Barnetby-le-Wold village

Closed loop GSHP

- With 738 homes, Barnetby-le-Wold village has a peak demand of 5166 kW.
- Based on an energy yield from the ground of 8kW, 646 closed loop boreholes will be required to meet this demand.
- These boreholes would require an area of 38,200m^2 (3.8 ha) – indicated on the figure opposite.
- The area indicated on the figure does not take into account existing buried features and an assessment of utilities would be required.

Deep geothermal doublet

- Alternatively, a deep geothermal open loop doublet, or multiple doublets may be possible. Our pre-feasibility estimate has concluded that each doublet could provide around 1 to 2 MWth.
- With deeper geothermal systems there is an inherent geological risk, in particular that the groundwater abstraction rates are not as high as anticipated.
- Indicative locations for a well doublet is shown on the figure opposite.



Possible area for a closed loop array to heat homes in Barnetby

Generation, Source & Network Opportunities
Geothermal

Heating requirements, CAPEX and physical constraints should be considered in the selection of a ground energy system.

Options assessment

The table below provides a summary of the energy available and an indicative capital cost for installation of the ground loops/well for each system. These costs exclude the heat pump and pipework/trenching from the boreholes to the energy centre. However, further evaluation is required prior to selecting a system.

Closed loop boreholes are likely to provide the most cost effective system in terms of capital costs, however may require a large footprint to achive the required heating/cooling demand. Additional costs associated with pipework and trenching to connect the borehole array to the energy centre will need to be considered.

A deep open loop doublet may have a higher capital cost, but the temperature of the water from the ground will be much higher and consequently the heat pump will be more energy efficient and lower cost to run over the project design life. An area of at least 0.25ha would be required during the drilling of each borehole. Once installed, each well will occupy an area roughly equivelant of a manhole.

Ground energy option	Borehole depth (m)	Energy from ground	Heat to buildings (kW)	CoP*	CAPEX #	CAPEX per kW	Other considerations
Closed loop borehole	200	8kW	12	3	£11.5k	£950	Footprint required for numerous boreholes, avoidance of utilities, trees, slopes, other physical constraints. Embodied carbon of the boreholes.
Open loop doublet	800 and 1000	1-2 MW	1.25-2.5MW	5	£2-4M~	£1000-3200	Avoidance of utilities, trees, slopes, other physical constraints. Risk that energy produced is less than anticipated.

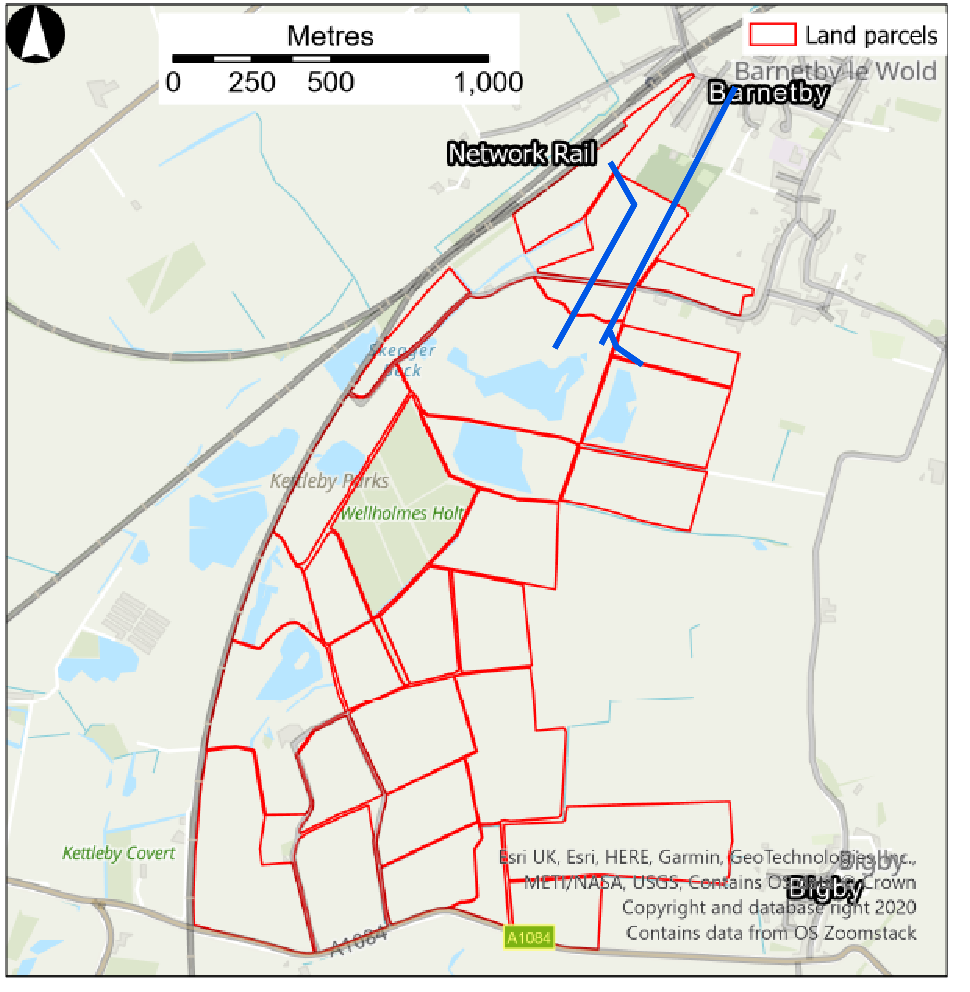
* Indicative CoP assuming output temperature of 65°C.
# CAPEX excludes the cost of design, testing and the cost of ground source heat pump and heat network
~ Costs are indicative and will need to be confirmed

Generation, Source & Network Opportunities
Water Source

Surface water potential

Surface water source heat pumps

- There are several ponds and lakes in close proximity to Barnetby-le-Wold and the Network Rail compound that could be utilised to provide heating/ cooling, possibly in combination with GSHP.
- Further assessment will be needed to determine the capacity of these water bodies, in particular the depth of the ponds// lakes and seasonal variations in water level and temperature.



Surface water ponds/ lakes within the site

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Capital Investment Opportunities

Capital Investment Opportunities
Investing in demand development

- There is a prospect for the Parish in terms of attracting the development of the identified demand not only in terms of creating market for the growth in energy provision but also inward investment to the local economy and the accompanying social value it brings.
- The demand types identified are estimated to amount to the shown capital investment opportunity to the respective developer markets:

Market	Demand type	Investment (£M)	Term (years)
Bigby Village	eHeat / EV	N/A	0-5
Barnetby Village	eHeat / EV	N/A	0-5
Humberside Airport	Power	N/A	0-5
Brigg Garden Centre	Power	N/A	0-5
Truck Stop	Power / EV	N/A	0-5
Data centre (enterprise)	eCool / Power	£100M*	5-10
Glasshouse	eHeat / Power	3.5M**	5-10
Anaerobic Digestion	Agro waste	N/A	5-10
Hydrogen production	Power	N/A	10-15

Potential capital investment opportunity

- **Ref T&T £10/Watt (exc CO_2 power plant) ***
- **Ref Arup £200k/acre ****

Capital Investment Opportunities
Investing in energy generation, source and network growth

- There is a prospect for the Parish in terms of attracting the development of the identified energy generation opportunities serving the short, medium and long term demands identified. These opportunities create inward investment to the local economy and the accompanying social value of employment in addition to affordable zero carbon energy.

- The energy generation prospects identified are estimated to amount to the shown capital investment opportunity to the respective developer markets:

* Maximum build-out: 75MWac with an annual energy yield of 78MWh, ground mounted solar PV is around £500/kWh to £530/kWh with an operational costs of £6/kW/year.

** The capital costs for the batteries is around £400/kWh to £480/kWh with an operational costs of £10/kW/year. The operational cost includes an allowance to counteract degradation such that the system will be able to perform at rated capacity throughout its lifetime.

***The capital costs for wind farm is around £1300/kW and an operational costs of £110/kW/year.

Market	Generation type	Investment (£M)	Term (years)
PV arrays	Power	*15.0M / 41.4M	0-5
Battery Storage	Power storage	**1.9M	0-5
Humberside Airport	Private wire	1.36M	0-5
Brigg Garden Centre	Private wire	1.0M	0-5
Network Rail	Private wire	0.18M	0-5
Truck Stop	Private wire	0.62M	0-5
Wind turbines	Power	***4.5M	0-5
Bigby Village	GSHP / EV	1.4M	0-5
Barnetby Village	GSHP / EV	10.3M	0-5
Anaerobic Digestion	Heat / CO2	3.5M	5-10
Network Rail	GSHP / Power	2.0M / 0.18M	5-10
Hydrogen production	H2 / storage	£8.6M/£18.3M	10-15

Potential capital investment opportunity

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4. Prioritisation

Identify Priority Opportunity
Comparative Assessment

IRM analysis

- A high-level Integrated Risk Matrix (IRM) has been developed to compare long list electricity and heat generation technologies.
- The IRM compares the long list technology options across financial, environmental, strategic, deliverable and technical criteria to establish the suitability of the options.
- The IRM has ranked Solar PV as the highest scoring option with Onshore Wind and Water Source Heat as the second and third options, respectively.
- Battery storage could be used alongside any of the electricity generation methods to increase electricity resilience.
- Although the IRM compares both electricity generation and heat generation options, these technologies can still be combined to form part of the same pathway.
- The results of the IRM will be used to develop a short list of technology options which should be explored further in a feasibility study.

	Financial		Environmental		Strategic		Deliverability	Technical		Total Score						
Criteria	Magnitude of Capital Investment	Magnitude of Operating Costs	Quantity of Emissions Savings 2050	Environmental Impact	Energy System Complexity	Commercial Complexity	Suitability of Phasing	Ease of Integration with Community Systems	Energy Supply Resilience	Financial	Environmental	Strategic	Deliverability	Technical	**Total Score**	**Ranking (All Technologies)**
Electricity Generation																
Ground-mounted Solar PV Array	4	4	5	4	4	4	5	4	3	0.89	1.00	0.89	0.56	0.78	4.11	1
Onshore Wind	4	4	3	2	4	4	3	4	3	0.89	0.56	0.89	0.33	0.78	3.44	2
AD Plant	2	2	2	2	3	3	3	3	4	0.44	0.44	0.67	0.33	0.78	2.67	7
Battery Storage	2	3	2	2	3	4	4	4	4	0.56	0.44	0.78	0.44	0.89	3.11	4
Heat Generation																
Ground source heat (Closed-loop)	3	3	3	3	2	2	4	3	4	0.67	0.67	0.44	0.44	0.78	3.00	5
Water source heat	4	3	3	3	3	2	4	3	4	0.78	0.67	0.56	0.44	0.78	3.22	3
Geothermal Resource	2	3	4	3	2	1	1	4	2	0.56	0.78	0.33	0.11	0.67	2.44	8
Hydrogen Genreation and Production																
Hydrogen	2	2	3	3	4	4	2	2	3	0.44	0.67	0.89	0.22	0.56	2.78	6

Integrated Risk Matrix (IRM)

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5. Commercialisation

Commercial opportunities for investors, operators and the community
Introduction

- The strategic opportunities identified and explored in this study have focused on renewable energy solutions serving existing and potential demands envisaged over the short term and into the future considering the regional and national net zero goals.
- The opportunities cover small scale localised solutions for the Parish community and businesses through to wider blue-sky thinking of larger scale solutions integrating with the wider region.
- Additionally, given the key Northern Power Grid electricity distribution system constraint which presently limits the rate and capacity of integrating renewable power generation in and around the Parish, considerable focus is also applied to developing additional business opportunities to grow demand locally thereby avoiding the need for NPG interconnection. While working within the constraint this approach also has benefits, it grows prospect for inward investment with jobs and economic benefits while also enabling larger renewable energy capacity opportunities.
- It remains for next stage investigations to quantify the investment opportunities and business case structure, however the demand growth and renewables solutions do represent a Parish vision prospectus for the community, local businesses and stakeholder and also outside investors and business developers.
- This section presents a formative view of the need for a commercial structure or structures to be developed appropriately for the investment solutions identified in the study. This is an introduction only to inform the perspective of the Parish Council and the likely development of a project relationship with the Local Enterprise Partnership, the Local and County Authorities with whom vested powers sit along with greater resource for procurement and central government support leveraging.

Commercial opportunities for investors, operators and the community
Commercial case structuring

- A Commercial Case formalised by the HM Treasury Green Book aim to demonstrate that the "preferred option(s)" will result in a viable procurement and well structured Deal.
- It also requires the spending authority to clearly specify the service requirements for the spending proposal in output terms, together with the anticipated charging regime and the allocation of risk. In addition it includes the contractual arrangements and specifies the accountancy treatment to be used for the proposed service.
- Arup with collaborating partners prepared guidance for BEIS in support of the completion of the Commercial Case for a heat network projects. This guidance is applicable to heat and power network development opportunities which have common aspects of the need to identify:
  - the different roles in the delivery of projects, and the risks and opportunities associated with each role;
  - typical contracts used to govern relationships between parties;
  - delivery models for heat networks, i.e. combinations of role allocations to different parties and the contracts which govern relationship between the parties; and tax and insurance implications.

Roles and Parties in Delivery

- There are certain roles that need to be performed if a project is to be successfully implemented. These roles should be distinguished from the parties that might undertake them, since one party may take multiple roles and, likewise, a role could be fulfilled by multiple parties.
- From an early stage in the project development cycle, the key roles are the Customers who will be supplied with energy and an entity which wishes to Promote the project to supply them.
- These roles along with eleven other roles need to be assigned in order to develop the delivery model. These thirteen roles are listed below.

1. Promotion
2. Customer
3. Governance
4. Regulation
5. Funding
6. Asset Ownership
7. Development of Property
8. Land Ownership
9. Landlordship
10. Installation
11. Operation
12. Sale of heat
13. Supplier of last resort

Parties will need to be identified who can take on the responsibilities, risks and opportunities associated with each role. In many cases the roles will fall naturally to one or more parties – the Landlord role, for example – but in other cases a deliberate choice will have to be made to play a particular role.

Commercial opportunities for investors, operators and the community
Commercial case structuring

- Parties for urban energy projects may include:
    - Local Authority (LA)
    - Developer
    - Energy Services Company (ESCo): a company that supplies and sells energy to customers.
    - Estate Management Company (ManCo): a body established by a landlord or a property's joint owners to manage and maintain that property.
    - Transmission Company (TransCo): a subtype of ESCo which supplies energy on a bulk purchase, or wholesale, basis only.
    - Community Body
    - Joint Venture (JV)
    - Special Purpose Vehicle (SPV)
    - Customer: includes tenants, leaseholders, owner-occupiers and business customers
    - Funder
    - Contractor: includes Design and Build (D&B), Operation and Maintenance (O&M) and DBOM.
    - Regulators to uphold common standards in the quality and level of protection given by supply contracts and offers customers an independent process for settling disputes.
    - Local authorities and community bodies should consider which roles they are undertaking or would choose to play in light of their drivers, circumstances and risk appetite.

Contracts Related to Heat Supply Networks

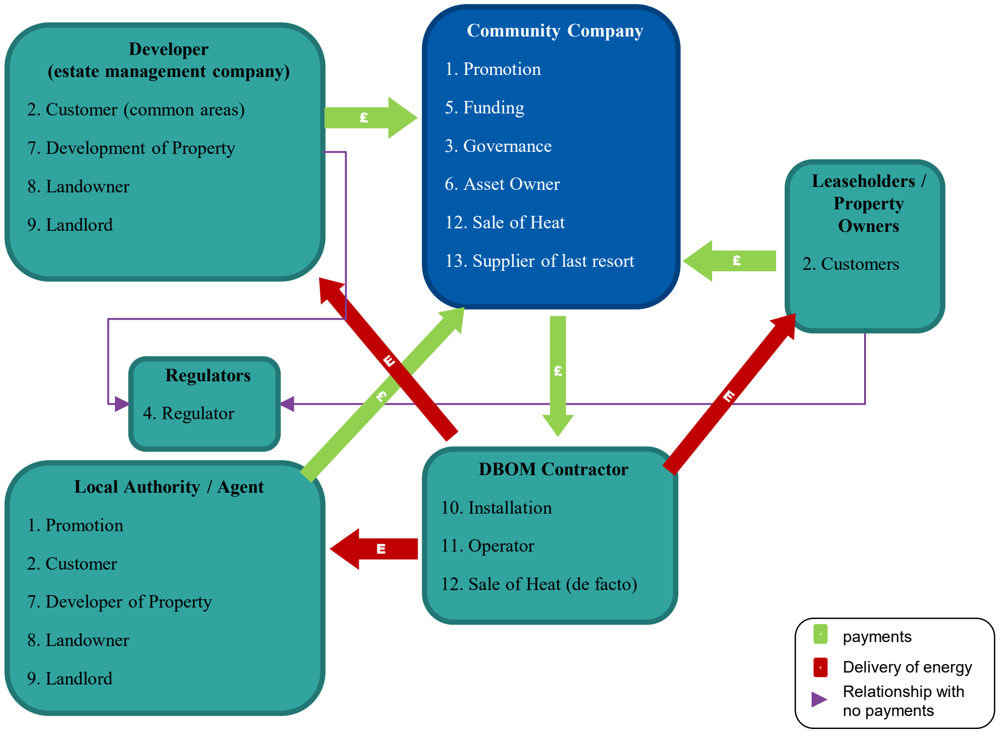
- The delivery and operation of heat networks are governed by a series of contracts and other forms of agreement between the parties involved. Some agreements are widely used in many other contexts, while others are unique, or uniquely applied to a heat network situation.
- The guidance provided by Arup and collaborators for BEIS "Heat Network Detailed Project Development Resource: Guidance on Strategic and Commercial Case." Issue 1.0 | 22 July 2016, provides typical forms of contract for heat networks and the situations when each would arise.
- Each type of contract requires Heads of Terms documents (HoTs) to be drafted as a starting point for developing bespoke agreements for particular heat network projects.

Delivery Models

- The arrangement of parties and roles into a defined set of relationships, responsibilities and rights is referred to as a delivery model.
- Delivery vehicles within this might involve formal corporate entities created for the purpose of heat network delivery (e.g. a Joint Venture body or Special Purpose Vehicle), or they may make use of existing organisational structures.
- Delivery models are typically conceived as ranging from "public" to "private" but in reality there are many potential combinations of parties fulfilling the various roles, and thus the choice of delivery model is more of a continuum of solutions rather than a defined set of solutions.
- Nevertheless, four main types of delivery model can be identified, depending on the parties undertaking the different roles:
    - Private sector led
    - Public-private shared leadership
    - Public sector led
    - Community company (CoCo)

Commercial opportunities for investors, operators and the community
Community Delivery Model Example

- Once all the roles have parties assigned to them it should be possible to determine the delivery model, or at least the type of delivery model, that is most appropriate to the project.
- The number of these roles that a Local Authority Party takes on will help determine the delivery model that is most suited to the scheme.
- In reality there are many potential combinations of parties fulfilling the various roles, and thus the choice of delivery model is more of a continuum of solutions rather than a defined set of solutions.
- Nevertheless, four main types of delivery model can be identified, depending on the parties undertaking the different roles:
    - Private sector led
    - Public-private shared leadership
    - Local authority / housing association led
    - Community company (CoCo)
- Once all the roles have been assigned, the list should be compared to how the roles are assigned for these four types as shown in the table overleaf.
- The roles identified and shaded in green for each of the four delivery model types are likely to define the most appropriate model for the delivery of the project.
- Defining what delivery model type your project falls into serves, in itself, little purpose, since it is the allocation of roles that will define the procurement route. The allocation of roles will also define the relationships and contracts that must be put in place to deliver and operate the network.
- Therefore for example the original driver may be for a Local Authority Led scheme, but assessment of the risks of each role may determine this is not appropriate.
- A Community company approach to delivery is illustrated.
- A next stage feasibility study would begin to identify the roles more clearly.



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4. Strategic Pathway

Strategic Pathway
Decarbonisation Pathway

2022-2027

- **Demand -** During the short term (0-5 years), the anticipated electric demand would be circa. 15MVA via Brigg Garden Centre, Humberside Airport, Truckstop, Village EV Charging and Existing electric heat demand at Bigby/Barnetby Villages
- **Generation -** The approximate generation required to meet peak demand would be:
  - Solar PV – 15MW
  - Battery Storage – 10MW
  - Village ground heat – 6.5MW
- **Network -** During this time, we proposed to private wire the potential offtakers such as Brigg Garden Centre, Humberside Airport and Truckstop

2028-2033

- **Demand -** During the medium term (5-10 years), the anticipated electric demand added would be circa. 18MVA via glasshouses, network rail development and data centres
- **Generation -** The approximate generation required to meet peak demand would be:
  - Solar PV – 20MW
  - Anerobic Digestion – 10MW
  - Battery Storage – 10MW
  - Commercial ground heat - ~24MW
- **Network -** During this time, we proposed to private wire network rail development.

2034-2039

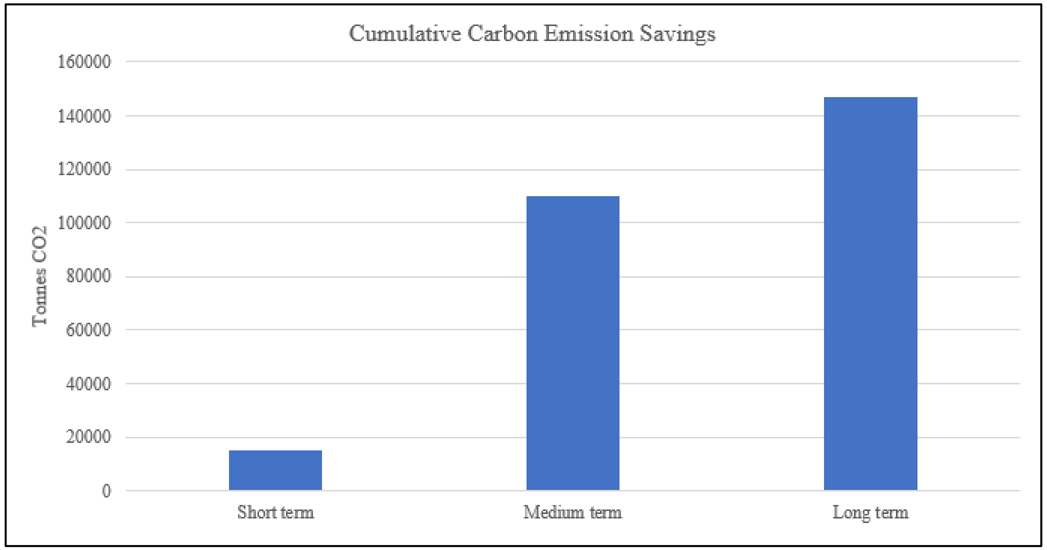
- **Demand -** During the long term (10-15 years), the anticipated electric demand added would be circa. 5MVA via hydrogen facility, which has a potential to grow in demand depending upon the applications and interests among the third parties around the area.
- **Generation -** The approximate generation required to meet peak demand would be:
  - Anerobic Digestion – 5MW
- **Network -** During this time, we proposed to provide on-demand hydrogen as a fuel to airport and truckstop or could potentially be utilized for heating purposes to nearby villages or network rail development

Strategic Pathway
Conclusion and Next Steps

- In the short term the demands and known growth amount to circa. 15MVA of electrical and electrified heat. There is therefore the prospects to generate this by renewable sources of energy from identifiable land areas.
- The immediate next steps to meet the anticipated short term growth in demand would be to develop PV installation co-located with battery storage. These technologies are ideally placed to be installed in phases to scale up during the anticipated medium and long term demands.
- The area network has an export only limitation on generation capacity operation. Private wire development connecting generation with demands can be synchronised with grid intake supply to the consumer subject to controls preventing export back onto the grid.
- In anticipation of the grid constraints during the short term period, there are at least four potential off-takers of generated electricity from solar PV co-located with battery storage. These off-takers include: Humberside Airport, Brigg Garden Centre and the soon to be developed A18 Truckstop.
- The majority of the medium term growth in demand would come from newly created synergistic businesses, i.e. horticultural glasshouse and data centre(s) and soon to be developed network rail development. These are newly located markets representing energy demand growth potential for private generation electricity and heat connection/supply. They represent prospects to local and wider market developers of industry and commercial operations locating in the Parish.
- The long term demand growth would be realised from Hydrogen demand around the area. Hydrogen could be utilised for truck refuelling at the Truck Stop development, alternative fuel at the Humberside Airport, dedicated pipework for heating purposes for network rail development or injection into the national grid gas network locally.
- Next steps for the Parish Council would be to create the agenda and awareness among the stakeholders for the huge development opportunity around the area.
- We recommend that detailed demand/generation estimation along with energy operational balancing models should be studied during a next stage feasibility study.
- The Humber region has wide area objectives and drivers which present significant location related prospects for the Parish council in the medium to long term i.e. CO_2 capture and hydrogen pipelines aligned with the Humber Industrial Cluster.
- It should also be said that gaining long term consumer commitment for energy supply from independent generators/suppliers can be perceived as a risk in terms of security, resilience and monopolistic. However, energy security, climate and affordability drivers are now in clear focus across the UK, so barrier to energy investment prospects are now more balanced by the incentives. This is recommended as part of the examination during the next steps of feasibility exercise and stakeholder engagement.

Strategic Pathway
Carbon trajectory of Bigby Parish Council

- As per potential demand/generation estimation during short term, medium term and long term timeframe, we have observed the overall carbon emissions savings highlighted in the figures to the right.
- These calculations are based on the additional generation capacity envisaged during the timeframe, as discussed in the Section 4: Strategic Pathway. We have assumed specific energy production of PV to be 950 kWh/kWp and 80% load factor of AD plant.
- The carbon emission savings are based on BEIS 2021 figures of 0.21233kgCO_2e/kWh. However, these values changes every year due to the decarbonisation of the grid. We recommend a detailed carbon emission estimation exercise be included as part of the feasibility study during the next stage of the project.
- While it cannot be precisely estimated at the stage, it can be stated that the amount of potential carbon savings will exceed the existing carbon emission of the Parish council and the identified businesses scope 2 emission by a significant factor and thereby transition Bigby Parish to a position of Net Zero Carbon.
- The investment prospect in the short to long term to achieve this transition to net zero carbon are considerable, estimated in this study to be:
  - Short-term 2022 to 2027 £37M
  - Medium-term 2028 to 2033 £110M
  - Long-term 2034 to 2039 £18M
- The considerably larger investment prospect in the medium term reflects an optimistic readiness of the area to attract the identified synergistic commercial developments seeking zero carbon energy while acceptingthat addition renewable capacity will be made possible by the upgrading of the NPG electricity network.



Cumulative Carbon Emission Savings for the Parish Council

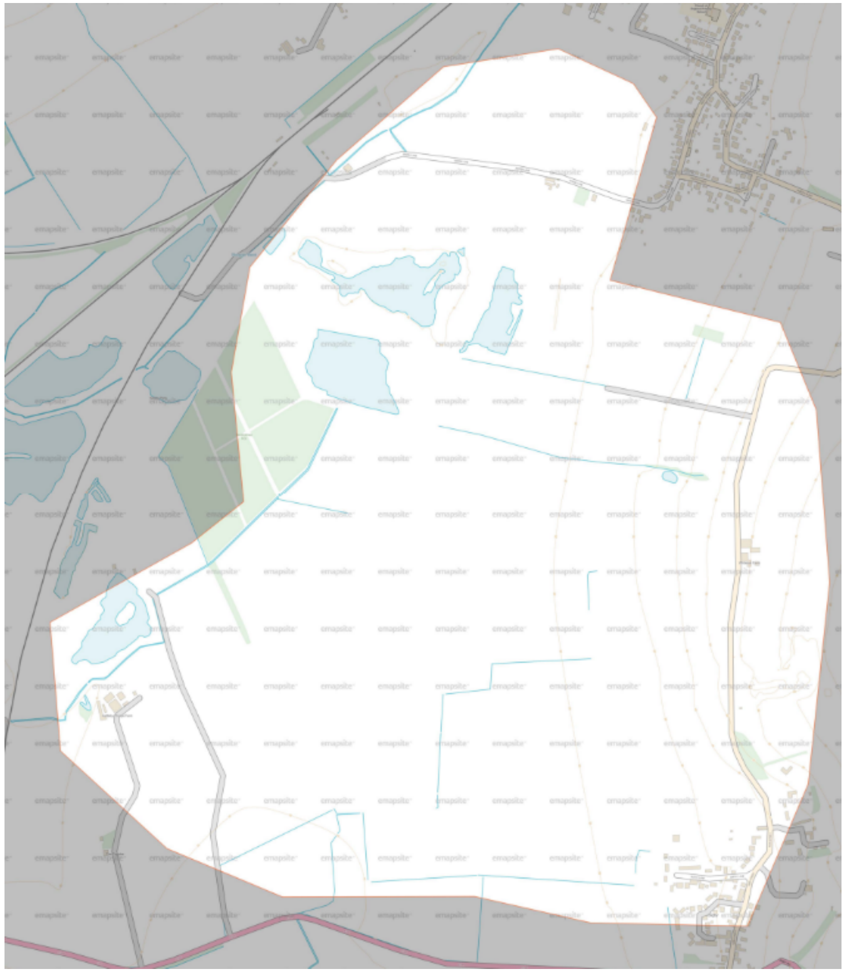
ARUP

Appendix

Appendix 1
Utility Search

Utility constraints

- As part of the utility research, we have completed a comprehensive review of affected utilities around the area (highlighted in the map to the right) including:
    - Electricity
    - Gas
    - Water
    - Telecom
- Arup has reviewed a detailed utilities report produced by third party Groundsure.
- It has been observed that the affected parties of services include:
    - Northern Powergrid
    - Cadent Gas
    - Anglian Water
    - BT Openreach
- The following pages in the report highlight the key findings from the Groundsure Utilities report. It is recommended to make further enquiries and investigations to satisfy as to the adequacy of the plans and position of the utilities.



Appendix 1
Utility Search

Electricity

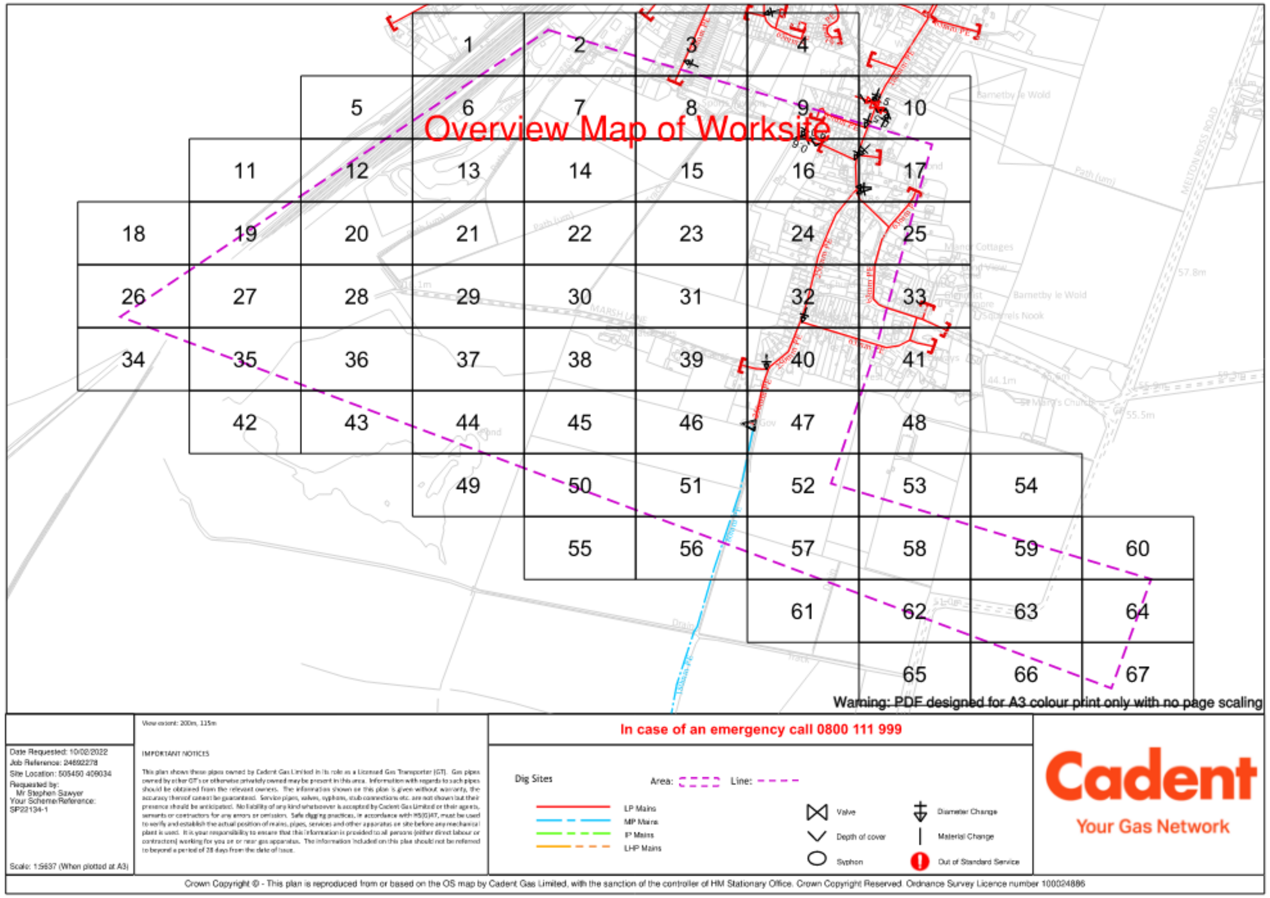
- Arup has performed grid connection assessment to connect energy generation assets around the area.
- The entire area is grid constraint and needs a network reinforcement works from Northern Powergrid.
- Still potential to build and provide private wire connection to airport/garden centre/onsite demand

Primary Substation (33/11kV)	Downstream constraint (11kV and below)	Upstream constraints (33kV and above)	Comments
Wrawby	0.190MVA	0.190MVA	The restrictions are mainly driven by the constraints on 33kV and above circuits, which has made same potential spare capacity at both downstream and upstream networks.

Appendix 1
Utility Search

Gas

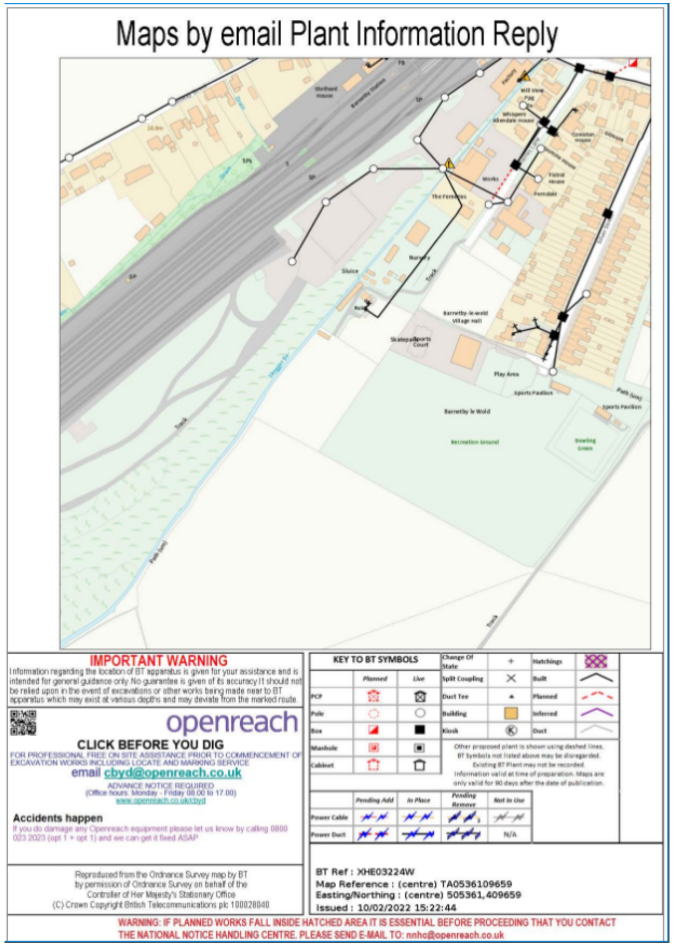
- Arup has performed an exercise to assess existing gas pipelines around the area including low pressure (LP) mains, medium pressure (MP) mains, intermediate pressure (IP) mains and low high pressure (LHP) mains
- There are low pressure Cadent gas pipelines around the area, particularly in the area feeding the Barnetby community as highlighted by the solid red line in the map to the right.
- However, these pipelines does not overlap to the anticipated energy infrastructure.
- The risk of existing gas pipelines interfering to the development is low or negligible.
- It is recommended that the appropriate code of practice shall be followed for the generation asset installation in the vicinity of buried pipelines, which in this case is LP mains.

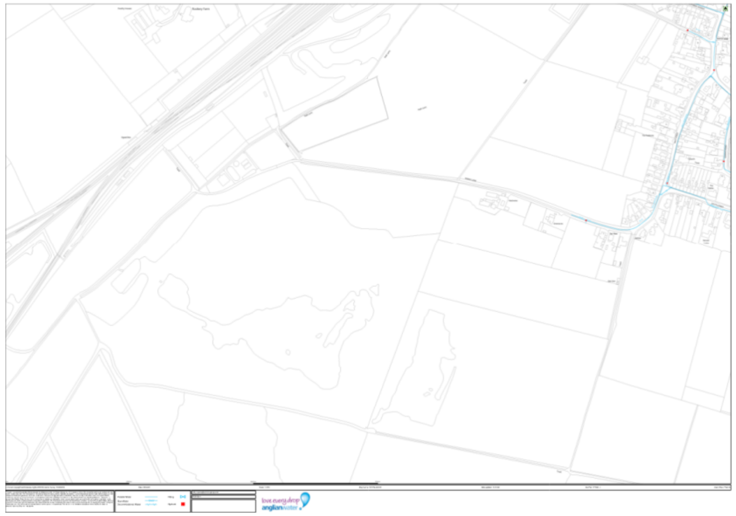


Appendix 1
Utility Search

Water and Telecom

- Arup has performed an exercise to assess existing water mains and telecom cables around the parcels of land.
- There are built telecom cables in the Barnetby region with no interference with an anticipated energy infrastructure development around the area.
- In terms of water mains, there are no existing water mains supply across the parcels of land, hence, there won’t be any interference with an anticipated energy infrastructure development.
- However, further investigation shall be required to consider private wire connections across the community region from the energy source.





Appendix 2
Comparative Assessment Rationale

Comparative Assessment Rationale (see next page)

	Financial				Environmental				Strategic				Deliverability		Technical			
Criteria	Magnitude of Capital Investment	RATIONALE	Magnitude of Operating Costs	RATIONALE	Quantity of Emissions Savings 2050	RATIONALE	Environmental Impact	RATIONALE	Energy System Complexity	RATIONALE	Commercial Complexity	RATIONALE	Suitability of Phasing	RATIONALE	Ease of Integration with Community Systems	RATIONALE	Energy Supply Resilience	RATIONALE
Electricity generation	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale	Score	Rationale
Ground-mounted Solar PV Array	4	*relatively low capex	4	*relatively low opex	5	*very high emissions savings compared to grid up to 2050.	4	*possible impact on land usage. Can be mitigated with hybrid usage site.	4	*low complexity, developed technology	4	*low complexity, developed technology	5	*highly incremental. Multi site installation possible. possible loss of economy of scale if not planned well	4	*few connection options available through private wire or virtual PW via existing DNO HV network.	3	*score due to unpredictability of output
Onshore Wind	2	*high overall capex due to large power installed increments	3	*relative to other electricity generation technologies	4	*very high emissions savings compared to grid up to 2050.	4	*possible impact on bats/birds. Minimal impact on land usage and vegetation.	4	*low complexity, developed technology	5	*low complexity, developed technology	3	*size of each phase is high. Possible loss of economy of scale	3	*few connection options available through private wire or virtual PW via existing DNO HV network.	4	*score due to predictability of output and downtimes
AD Plant	2	*high overall capex	2	*high operating costs due to technology	2	*low emissions saving due to technology	2	*high impact due to emissions from technology	3	*complex technology, needs site management	3	*average complexity	3	*can be phased in but will involve site works	3	*potential connection options	4	*score due to predictability of output and downtimes
Battery Storage	2	*high overall capex due to materials	3	*average operating costs due to technology	2	*will only support emission savings if paired with low carbon technology	2	*high impact due to materials required	3	*needs to be used in conjunction with other technologies which can make the system complex	4	*low commercial complexity	4	*incremental technology, can be phased inline with other technologies	4	*can be easily integrated with other technologies	4	*score due to predictability of output and downtimes
Heat Generation																		
Ground source heat (Closed-loop)	2	*relatively high capex associated with borehole infrastructure (closed-loop boreholes circa 200m depth)	2	*relatively high operating costs associated with energy centre, distribution infrastructure and ancillary equipment and electricity to ground source heat pump. Additional costs associated with pumping circulating fluid around the boreholes.	3	*moderate emissions savings, emissions dependent on emissions intensity of electricity source used to supply pumps and heat pump	3	*temporarily drilling boreholes - longer term relatively low (pipes in the ground with relatively impact on the ground - dependent on refrigerant)	2	*relatively high complexity, requires energy system operator, operation of heat network, interface with building envelope, management of energy centre and ancillary equipment, additional complexity associated operation and management of ground heat recovery infrastructure	2	*relatively high, requires energy system operator, new commercial arrangements for heat network system and the development of heat supply agreements with energy consumers	3	*moderate suitability, borehole array can be scaled to meet demand, but heat network pipes may require extra capacity to facilitate future expansion (this may reduce operating efficiencies in the short term)	4	*relatively simple integration. Requires connection of energy centre to heat distribution infrastructure.	4	*relatively high level of confidence associated with thermal yield of closed-loop boreholes, which also have high design life. Some risk associated with thermal degradation of ground (due to over extraction of heat), and damage to heat distribution infrastructure.
Water source heat	4	*relatively low capex - capex associated with water abstraction infrastructure	3	*moderate operating costs associated with energy centre, distribution infrastructure and ancillary equipment and electricity to water source heat pump. Some additional costs associated with pumping recovered water from the water source to site and to reinjection point.	3	*moderate emissions savings, emissions dependent on emissions intensity of electricity source used to supply pumps and heat pump	3	*environmental impact associated with water source heat recovery infrastructure. Operation needs to ensure an acceptable level of impact on water levels in surface water sources (e.g. rivers) and acceptable level of impact on ecology	3	*moderate complexity, requires energy system operator, operation of heat network, some additional complexity associated with operation and management of water abstraction infrastructure	2	*relatively high, requires energy system operator, new commercial arrangements for heat network system and the development of heat supply agreements with energy consumers	3	*moderate suitability, water source heat recovery may be able to be scaled to meet demand (subject to capacity of water source), but heat network pipes may require extra capacity to facilitate future expansion (this may reduce operating efficiencies in the short term)	4	*relatively simple integration. Requires connection of energy centre to heat distribution infrastructure.	4	*relatively high level of confidence associated with thermal yield of water source heat recovery system.
Geothermal Resource	2	*high costs associated borehole infrastructure (open-loop borehole up to 1km)	3	*relatively high operating costs associated with energy centre, distribution infrastructure and ancillary equipment. Additional costs associated with pumping recovered water out of the boreholes and reinjecting back into the ground.	4	*high emissions savings, emissions dependent on emissions intensity of electricity source used to supply pumps	3	*temporarily drilling boreholes - longer term relatively low (pipes in the ground with relatively impact on the ground), a water abstraction license with the Environment Agency (EA) will be required	2	*relatively high complexity, requires energy system operator, operation of heat network, interface with building envelope, management of energy centre and ancillary equipment, additional complexity associated operation and management of geothermal infrastructure	1	*very high, energy system operator, new commercial arrangements for DH system and houses, geological risk due to required investment and uncertainty associated with thermal yield of the ground at depth	1	*low suitability, difficult to scale due to nature of deep geothermal borehole & heat network infrastructure (although additional borehole may be added if sufficient demand exists).	4	*relatively simple integration. Requires connection of energy centre to heat distribution infrastructure.	2	*relatively low level of confidence associated with thermal yield of the open-loop system.
Hydrogen Generation and Production																		
Hydrogen	4	*relatively low capex	4	*relatively low opex	5	*very high emissions savings compared to grid up to 2050.	4	*possible impact on land usage. Can be mitigated with hybrid usage site.	4	*low complexity, developed technology	4	*low complexity, developed technology	5	*highly incremental. Multi site installation possible. possible loss of economy of scale if not planned well	4	*few connection options available through private wire or virtual PW via existing DNO HV network.	3	*score due to unpredictability of output