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DRAFT REPORT

NASSINGTON ENERGY AND THERMAL OPTIONS APPRAISAL

For Nassington Energy and Thermal

04 April 2025

LOCOGEN

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EXECUTIVE SUMMARY

To be completed at project close.

TABLE OF ABBREVIATIONS

Abbreviation	Description
°C	Degrees Celsius
4G	4th Generation district heat network
5G	5th Generation district heat network
A2W	Air-to-water
ACH	Air Changes per Hour
ASHP	Air-Source Heat Pump
BESS	Battery Energy Storage System
BAU	Business as Usual
CAPEX	Capital Expenditure
CEF	Community Energy Fund
CO_2	Carbon Dioxide
COP	Coefficient of Performance
DERMS	Distributed Energy Resource Management System
DEVEX	Development Expenditure
DH	District Heating
DHN	District heat network
DHW	Domestic hot water
DNO	District Network Operator
EFM	Energy Flow Model
EICR	Electrical Installation Condition Report
EPC	Energy Performance Certificate
ENA	Energy Networks Association
GDL	Gardens and Designated Landscapes
GMPV	Ground-Mounted Solar PV
GSHP	Ground Source Heat Pump
GSP	Grid Supply Point
HIU	Heat Interface Unit
IRR	Internal Rate of Return

km	kilometer
kW	Kilowatts
kW/K	Kilowatts per Kelvin
kWh	Kilowatt Hour
LB	Listed Building
LNR	Local Nature Reserve
MATZ	Military Air Traffic Zone
MOD	Ministry of Defence
MW	Megawatt
MWh	Megawatt Hour
NATS	National Air Traffic Services
NPPF	National Planning Policy Framework
NPV	Net Present Value
OHL	Overhead Line
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
PROW	Public Right of Way
PV	Photovoltaics
RAF	Royal Air Force
RMPV	Roof-Mounted Solar PV
SAC	Special Area of Conservation
SAM	Scheduled Ancient Monument
SINC	Site of Importance for Nature Conservation
SPA	Special Protected Area
SPONS	Standard Price Other Non-Specific
SSSI	Sites of Special Scientific Interest
TRL	Technology Readiness Level
TRV	Thermostatic Radiator Valve
UFH	Underfloor Heating
WSHP	Water-Source Heat Pump

1. INTRODUCTION

1.1 Project background

The Nassington Energy and Thermal (NEAT) Project team, with the active support and partnership of the Nassington Parish Council, has appointed Locogen to complete an options appraisal for Nassington, with the target of exploring the feasibility of low-carbon, energy-saving solutions across the village. These options include electricity- and heat-generation, expanding beyond conventional direct-to-grid solutions, to assess the viability of targeted energy use reduction, emissions saving/offsetting, and eradicating fuel poverty.

NEAT's ultimate aim is to provide a secure, sustainable, cost-effective and clean energy and heating solution for the benefit of everyone in the village, regardless of income, home ownership status or house type. This is a holistic, inclusive and ambitious project to remove the village's dependency on oil and gas, promising multiple benefits to our community while accelerating a fair transition to net zero.

NEAT's overarching goals are to:

1. vide a sustainable, reliable and secure supply of renewable electricity and heat energy for decades to come.
2. Cut the harmful emissions that pollute our air and contribute to global warming.
3. Help to reduce or remove fuel poverty.
4. Create more financial and energy predictability, removing our dependence on fluctuating global energy prices, and shoring up the long-term prosperity of our village.
5. Provide residents with the same temperature of hot water and central heating as existing oil or gas boiler at equivalent or lower cost.
6. Accelerate and make a meaningful contribution to the UK's transition to net zero, by supporting residents and removing physical, emotional and economic barriers.
7. Provide economic Electrical Vehicle charging for Nassington residents, without home charging.

1.2 About Nassington

Nassington is a village and civil parish in North Northamptonshire, England. The village is on the River Nene and the border with Cambridgeshire, around 8 miles (13 km) west of Peterborough. The village is home to around 870 people (according to 2021 Census) living in c. 400 homes. Home ownership levels are high, around 70% being owned outright or with a mortgage. 18% of homes are social rented accommodation, slightly higher than UK average rates of social housing. There is a range of housing types, typical of rural English villages, from a high number of larger period properties (some with Listed status, where retrofit is very difficult / prohibited), large luxury homes with private pools, to small 1960s bungalows and modern houses built within the last 5 years. The village is home to a large Medieval church, the Prebendal Manor house (the oldest house in the county dating back to Anglo-Saxon period), primary school, pre-school, thriving cricket club, two pubs and various small businesses (village shop, butchers, hairdressers, tearoom and holiday cottages).

Nassington's draft neighbourhood plan makes provision for 41 new dwellings in Nassington between 2021 and 2031, across two sites. The larger site also includes plans for a new community 'hub' to replace the village hall and a small play area.

1.2.1 Existing and Proposed Heating / Energy systems

The primary heat source in the village is oil (thought to be around 2/3rds of the village dwellings), where individual homes have oil tanks and oil boilers. The village is not connected to the gas main network, but some homes have gas boilers and individual LPG storage tanks. Roughly 1/6th of the dwellings have electric heating in some form including air source heat pumps, some ground source, and some homeowners have invested in solar PV systems.

1.3 Project aims

NEAT are interested in exploring the feasibility of a set of complementary heating/power solutions, including:

- **Heating**: air-source, ground-source and/or potentially water-source heat-pump solutions, including:
  - Ambient heat loop networks, including a Kensa-style closed loop model, akin to the 'heat-the-streets' project, that does not require an energy centre.
  - Higher temperature 'traditional' district heat networks, potentially comprising modular heat pump cascade systems like those developed by HS Tarm in Denmark.
  - Solutions to improve energy efficiency.
  - Back-up / heat storage as may be needed.
- **Energy**: A new renewable energy source to power the heat pumps, potentially wind, solar or hydro, depending on technical feasibility, with consideration of a Battery Energy Storage System (BESS), to allow for peak time energy needs and avoid grid supplied electricity as much as possible.

NEAT are also interested in advice on grid capacity in/around Nassington and creative options for behind-the-meter solutions, micro-grids and smart technologies to balance demands, especially recognising the new housing and the opportunity this provides.

Ideas on alternative solutions that provide similar benefits at lower cost are also of interest. For example, the development of sand batteries for heat storage in Finland.

1.4 Project objectives

The objectives for the project are:

- to assess viable heat and power options for the village;
- to present options with financial projections, costs and benefits, to enable decisions to be made; and
- to provide a recommendation and performance specification for the proposed systems.

2. SITE

Nassington is a thriving North Northamptonshire village comprising a diverse range of housing types. There are a number of listed buildings within the village centre and consideration of the village character is important to any solution proposed.

Predominantly privately owned, there is also a significant proportion of social housing. The village is off-gas, with the majority of domestic heating and hot water provided by oil, with some LPG and electricity based systems, including some air source heat pumps.

The land to the east of the village, either side of the River Nene, is classed as a flood alert area.

Figure 1: Satellite view of Nassington (Google Earth image)

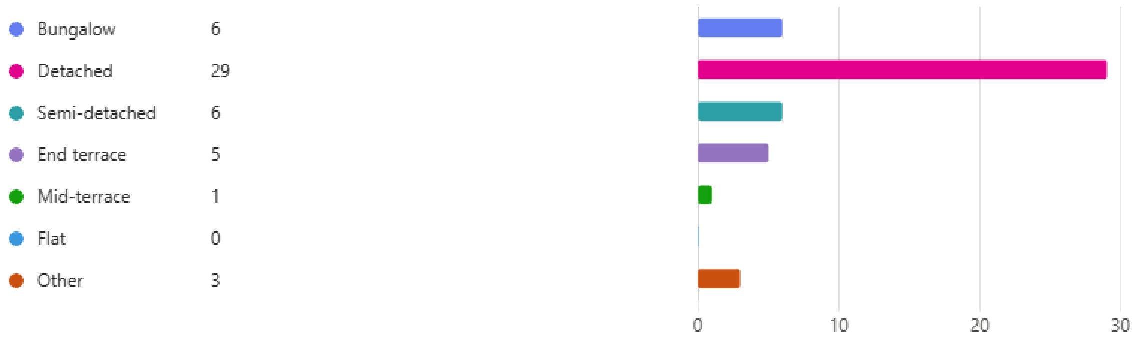
The key source of renewable energy considered in this study is ground source heat pump(s), and there is ample ground space available for boreholes as the heat extraction source. The surrounding fields also provide sufficient space for a large solar array or wind turbine to be potentially explored in order to help meet the electrical demands pulled by the GSHP.

2.1 Survey results

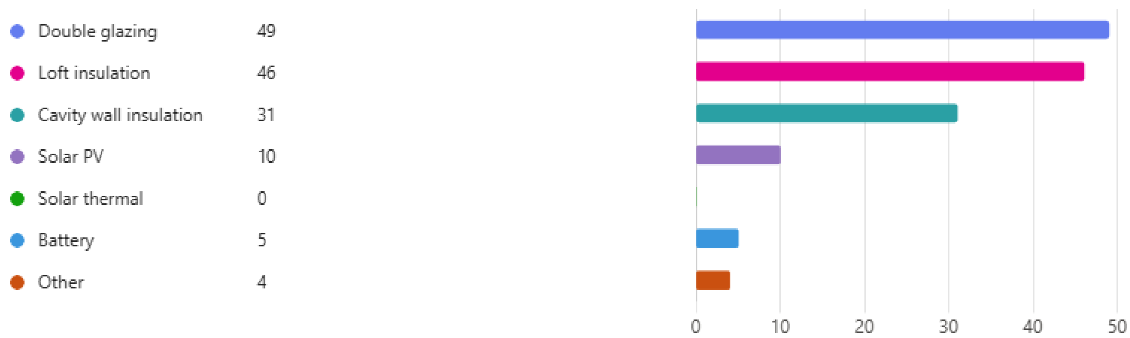
A survey was created and circulated to Nassington householders in order to gather feedback on current heating systems, future low carbon ambitions and current household energy usage.

These findings can be summarised as follows:

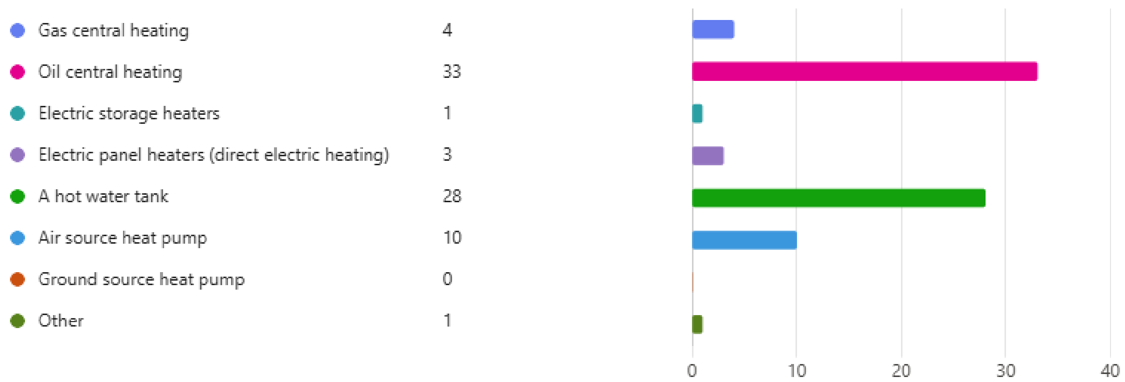
3. What type of house do you live in?



9. Do you have any of the following? (Please select all that apply)



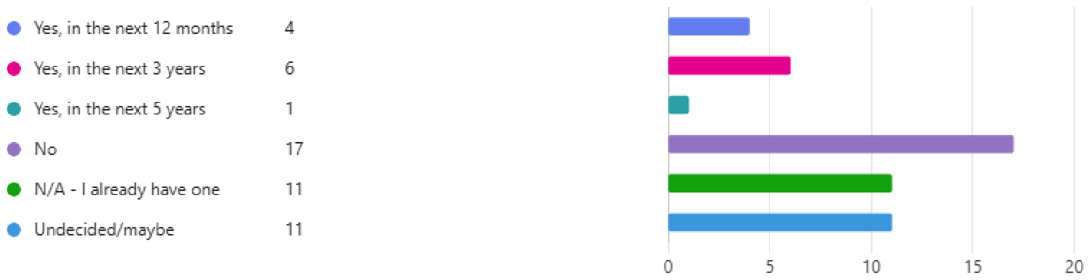
11. Which of the following do you have at home?



17. Do you have future plans to change/electrify your existing heating system?

18. Do you have an electric vehicle charge point?

19. Do you have any future plans to install an electric vehicle charge point?



2.2 Comparison with the UK Non-Gas Map

The non-gas map is a detailed map of Great Britain showing the distribution of properties without a gas grid connection and is available online here: https://www.nongasmap.org.uk/.

The non-gas map does not provide detailed figures for Nassington, but rather the East Northamptonshire district as a whole.

Of the 856 properties within the area of the map defined as 'East Northamptonshire 001C':

1. 95% of these properties are off the gas grid.
2. 491 (57%) of these properties are detached. Nassington survey responses were 58% detached.
3. 506 (62%) of these properties use oil for central heating. Nassington survey responses were 66%.
4. 105 (12%) of these properties are heated electrically (which includes heat pumps). 20% of Nassington respondents use heat pumps.

These findings show that the survey responses and the non-gas map are relatively well aligned and that there is a reasonable level of confidence in the survey responses received.

3. TECHNOLOGY

The following section sets out the main bulk of the feasibility study, exploring the different options to provide low-carbon heat and electricity to residents of Nassington.

This includes a review of low-carbon heating solutions and the variety of district heat networks that these could work in conjunction with; a review of wind, solar and battery storage opportunities, and an examination of what other measures could be implemented across the village to reduce energy demands and support NEAT's overarching goals.

3.1 Heat

3.1.1 Overview

The technology at the focus of this study is district heating heat pumps, including ground-source heat pumps (GSHPs) and air-source heat pumps (ASHPs). Standalone air-to-water (A2W) heat pumps, installed individually at each property have also been considered for comparison purposes.

Either ground-source or air-source heat pumps can be used in a 'centralised' solution, where a centrally located energy centre which houses the heat pumps provides heat to buildings within an area through a network of heating fluid at a high temperature (c.60°C+); or each property can be fitted with a domestic sized ground-source heat pump in a 'decentralised' arrangement, where each property pulls heating fluid at an ambient temperature (15-30°C) from a network. Air-source heat pumps would not be suitable for a decentralised arrangement, but will be considered as an alternative distributed solution, where each building is fitted with its own ASHP.

For a 'centralised' solution, each building would typically be fitted with a packaged Heat Interface Unit (HIU), where heat would pass from the network to the building, from which it would be circulated as per a conventional heating system. A hot water cylinder is not required, but may be wanted by property owners, depending on the nature of the buildings. HIU's would be installed inside the building.

Where a 'decentralised' solution was utilised where each property had its own heat pump, GSHPs units can either be installed internally or externally. Where installed internally they would require dedicated plant space (such as a utility cupboard, or existing boiler room), which can be limited in the buildings that currently use electric heating or have small oil boilers. Heat pumps are installed externally but do generate break-out noise (like a fan) and are not sympathetic with regards to their appearance in conservation areas, so have to be carefully located. Both types of heat pumps generate 'low grade heat' (i.e. lower operational temperatures than conventional oil boilers). In order to rectify this, the standard approach is to review and, where necessary upsize radiators and pipework within the buildings to reflect the lower flow and return temperatures. This is the approach outlined within the MCS domestic heat pump guidance. Alternatively, some users have adopted for a system where they adapt their heating profiles, so that the heating runs on for longer at the lower flow temperatures, often supported by a backup or secondary heating system for times of extreme cold, or to overcome the thermal inertia of the building after a period of not heating. Some people report that their houses feel colder once a heat pump system is installed, but heat pumps can maintain normal temperature set points, it is just that radiators typically feel cooler to the touch and have a lower radiative component, and rooms may require more time to get up to temperature.

Furthermore, heat pump systems do not produce instantaneous domestic hot water (DHW) (like a combi-boiler) and require space for a DHW cylinder to be installed. Most older houses have space for an airing cupboard but where combi-boiler systems have been installed this has typically been repurposed.

3.1.2 Equipment

District Heat Networks (DHN)

A heat network is a distribution system of pipework that facilitates the delivery of heat from one or multiple sources to more than one building. The heat source could be a boiler, heat pump and/or an ambient heat source. Heat networks are well established systems, especially in Europe, and are anticipated to play an important role in the decarbonisation of heat in the UK in order to meet net zero targets set by the government. The design of heat networks has changed over the years, which vary in many ways but some of the key variables are the pipework materials, level of insulation, flow temperatures and return temperatures. Whilst each heat network is slightly different, it can usually be classified into one of five generations of heat networks that have been defined. First and second generation heat networks are outdated systems that were developed in the late 1800s and early 1900s respectively. Most heat networks that exist today are 'centralised' third and fourth, or 'decentralised' fifth generation networks.

Generally, heat networks can be classified as either having a 'hot' or 'ambient' loop. A hot loop system would have a large, centralised heat source, like a ground source heat pump, which would supply heat directly each through a plate heat exchanger installed at each building. Both 3rd and 4th generation DHNs are both 'hot' network options, but vary in the temperature that the heat is distributed. In a 5th generation ambient loop GSHP system, the below-ground collector system is shared as in the 'hot loop' case, but individual heat pumps would be installed within each building. This means there is no discernible energy loss in the distribution pipework as the temperature rise in undertaken at each individual property. There are advantages and disadvantages for both systems which are noted below in Table 1.

Table 1: Advantages and disadvantage of centralised and shared loop heat networks

	Ambient shared loop	High temperature district heating network
Domestic upgrades	In order to operate most effectively, heat pump systems may either require the internal distribution systems to be upgraded, or the building fabric to be insulated. If required, radiators 2-2.5 times larger will be required, but this is subject to survey (especially where the heating system was installed prior to thermal upgrades). Work can be done on a property basis, with no impact on other users.	High temperature networks can operate at temperatures similar to existing domestic boilers, but for the best efficiencies the temperatures should be lowered where possible, ideally to those similar for individual heat pumps. The operational temperature of the network is determined by the highest temperature consumer, so a co-ordinated plan is required.
Space requirement	While an energy centre is not necessary, a small pumping station will be required. This is typically the size of a small shed. However, internal cupboard space at each dwelling for the heat pump and where combi-boiler solutions are currently used, DHW cylinders will need to be installed.	An energy centre would be required. This would house the main and backup boiler plant, distribution pumps and control infrastructure, typically the size of 1-2 shipping containers. This is in addition to internal cupboard space within each building for the HIU.
Distribution losses	As the system circulates ambient water, low or zero distribution losses are incurred.	Distribution losses occur as the system will circulate constantly at temperature. For a third generation network, losses are typically equal to 100% of the village delivered heat demand. For a 4th generation network, an initial estimate for standing network loss is equal to 25-50% of the village delivered energy demand (subject to optimisation).

Metering and billing	Where each property supplies electricity to their own heat pump, only a network standing charge or network ambient heat charge is levied (depending on the model - to cover system CAPEX recovery). However, where local generation can be supplied, the heat pumps would require to be networked together, and heat provided to each property on a metered basis.	Metering is required and measured on a heat meter at the HIU interface.
Maintenance and operation	The heat pumps will be required to be serviced annually. This can be tied into a service contract or arranged individually. Additionally, there is an annual inspection required of the ambient network pump and glycol levels.	Regular maintenance and operations management are required for the energy centre and heat network. Additionally annual maintenance of the HIU and meter reading is required.
Grid connection	Where buildings require large GSHP units (in excess of ~15kW depending on manufacturer), a three phase grid connection would be required. This significantly limits the ability to connect many larger properties to heat pump systems.	The grid capacity is only required to the energy centre and thus no grid connection constraints are applicable to individual buildings
Resilience and backup	In the case of an ambient loop system, if one heat pump fails, this only affects a single house (similar to the current boiler arrangements). Immersion heaters would be fitted to all DHW cylinders as backup hot water provision. The only centralised plant is the ambient distribution pump, which can either be set up as a duty/standby system, or a spare pump in storage onsite for exchange.	As the plant is centralised, a backup boiler or shared duty arrangement is required to provide failsafe arrangements. As with the ambient system, shared pumps can either be set up as a duty/standby system, or a spare pump in storage onsite for exchange.

For clarity, notes on 3rd, 4th and 5th generation networks have been set out below:

- 3rd generation district heat networks
  - Heating fluid in the system is typically 70-90°C.
  - High losses are incurred within the network – typically around 100% of the total heat demand.
  - 3rd generation heat networks that are powered by heat pumps typically see a low seasonal coefficient of performance (COP).
  - No internal pipework/radiator changes or changes to heating regimes are required at properties as heat is provided at the same temperature as a conventional oil/electric boiler.
  - No domestic hot water cylinder is required.
- 4th generation district heat networks
  - Heating fluid in the system is typically ~60°C.
  - Lower losses are incurred within the network – estimated to be around 25% of the total heat demand.
  - 4th generation heat networks powered by heat pumps see a better coefficient of performance than 3rd generation as heating output is lower.

- Some internal pipework/radiator changes or changes to heating regimes are required at properties as heat is provided at a lower temperature as a conventional oil/electric boiler.
- A domestic hot water cylinder with immersion back-up may be required, as temperatures seen 'at the tap' are likely to be in the region of 45-50°C, which for some houses or properties with catering facilities may be too low. The immersion heater can boost these temperatures higher.

- 5th generation district heat networks
  - Heating fluid in the system is typically 15-30°C.
  - No losses are incurred within the system.
  - The 'ambient' temperature heating fluid supplied to each property is boosted to a higher temperature through a domestic-sized heat pump within each property.
  - 5th generation heat networks powered by heat pumps see a better coefficient of performance than 3rd and 4th generation as heating output is lower.
  - Internal pipework/radiator changes or changes to heating regimes will be required at properties as heat is provided at a lower temperature as a conventional oil/electric boiler.
  - A domestic hot water cylinder is required.

Heat pumps (generally)

Heat pumps take heat from within the air, ground, or a body of water, compress it to raise the temperature, and then extract the heat into a heating fluid, to be used to heat radiators or water within a hot water cylinder. The efficiency of a heat pump is measured by its 'coefficient of performance' (COP), which is typically given as a number. This number is the total units of heat that can be generated from 1 unit of electricity. For example, a heat pump with a COP of 3 can generate 3 units of heat from every 1 unit of electricity.

This COP value changes over time, particularly as the temperature of the air, ground, or water body changes in temperature. Below ground temperatures and larger bodies of water in the UK maintain a relatively stable temperature throughout the year, but in the case of air-source heat pumps, when air temperatures fall, the efficiency of the heat pump will decrease as the heat pump works to abstract heat from the colder external air.

Ground source heat pumps (GSHPs)

GSHPs utilise heat contained within the ground to heat a 'heating fluid' such as a glycol/ water mixture to transfer heat, typically to a conventional radiator circuit (known as a wet circuit). The heat pump itself is installed in a plantroom (or similar) within the building. The below-ground collector circuit is either composed of boreholes, which are drilled to a depth determined through a geotechnical survey, or pipework installed at a depth of approximately 1.2m in trenches. While installing pipework in trenches is a cheaper option than drilling boreholes, it also requires significantly more space and as such, recommendations within this report have been based on the available external space at the locations considered.

The difference in temperature between the flow and return temperatures provided by a GSHP is lower than those generated by a conventional gas boiler and as such, radiators may be required to be bigger than those seen in a modern fossil fuel-fed system and the same considerations set out above will apply. Alternatively, heating regimes will need to be adjusted to ensure that heating is in operation for much longer periods of time to maintain room temperatures. Heat pumps can provide heat at different temperature levels, but the higher the distribution temperature, the more electricity is required to operate the heat pump, making it more costly to operate.

Air-to-water (A2W) heat pumps

An air source heat pump (ASHP) essentially involves an exchanger unit, almost always located against the external wall of a building, which will use electricity to heat up an internal wet distribution system or air convectors. They are typically simpler and less expensive than GSHP systems, although they can be used in heat networks too. The two principal variants of ASHPs systems: air-to-water systems and air-to-air systems – as this project will involve connecting into existing radiator systems, air-to-air systems have been disregarded.

In A2W systems, the generated heat is transferred to water which is then circulated through the building in a conventional wet radiator circuit. This system can be controlled with thermostats installed on radiators or within key rooms in the same way that any conventional gas- or oil-fired radiator system.

As highlighted with GSHPs, one of the key considerations with regards to A2W heat pumps is that the temperature of the hot water generated (or more technically, the difference in temperature between the flow and return temperatures within the circuit) is lower/smaller than what would be achieved by a gas-fired boiler and, as such, radiators are required to be much bigger to emit the same amount of heat to meet the rooms heat demand. Where smaller radiators may be present, these radiators would have to be replaced with radiators with greater surface area in order to meet the heat demands of each room. This would then introduce additional costs to the installation, the cost of which would be determined through a full heat survey.

Heat pump cascade systems

NEAT expressed a specific requirement to review a more modular, pre-assembled, clustered, heat pump cascade system, for example, like those developed by HS Tarm in Denmark. This is a system with a set of decentralised, high temperature heat stations or 'mini plantrooms' that each serve a smaller number of houses. Review of the HS Tarm system suggests that the system has a central spine that links each mini plantroom together, back to a central biomass boiler. Locogen does not recommend biomass as is no longer considered to represent a low-carbon solution.

The advantages of this system mean that the network can be segmented into smaller points – like 'microgrids' for heat, with each plantroom serving a smaller number of houses. Plantrooms would be smaller than a large energy centre designed to service a full district heat network and the system would have less network losses when considering a high temperature district heat network.

In addition, where a private wire from any proposed generation (such as a solar PV plant or wind turbine) is used to offset electricity costs, the cascade system has the advantage of comprising less points to run the private wire to (in comparison to running a private wire to each individual property fitted with a heat pump under an ambient shared loop scheme).

This solution provides the option to segment and make the network smaller, with each plantroom having its own heat-generating plant; or plantrooms could be interconnected to provide increased resilience.

However, the major drawback of this solution is the siting and location of the smaller plantrooms. With a typical district heat network, there is a centralised location for one energy centre, containing the heat-generating plant and any backup plant. With the HS Tarm system, there is a requirement for multiple plantrooms, with multiple heat-generating plant and multiple backup solutions.

This is not to say that this solution is not feasible, but would require further development and is an opportunity to be explored at the next stage of the project – detailed feasibility – with input from the Local Planning Authority and heat network contractors, to better understand the suitability of this option for Nassington.

3.2 Electricity

3.2.1 Overview

NEAT are also interested in exploring renewable electricity generating options in the form of solar PV and wind energy generation. Battery Energy Storage Systems (BESS) have also been included within this section as they are considered to be a 'generating asset' for the purposes of a grid application.

Note that for wind and solar PV, there are multiple ways that this could be used to offset electricity demand, as follows:

- For a 3rd or 4th generation district heat network (high temperature), the generating technology is connected via a 'private wire' to the energy centre, to offset the electricity demand of the heat pumps/heat storage.
- For a 5th generation district heat network (ambient loop), the generating technology is connected via a 'private wire' to each individual household connected to the heat network to offset the electricity required for each individual heat pump.

While the first option is commonly used, the latter is not, and Locogen have not identified a scenario where this has been done before in a heat network scenario. This is due to each property now having two power supplies – one from the grid, and one from the private wire. This introduces safety issues with isolating houses from the power supply.

3.2.2 Wind

Wind turbines operate by wind turning the propeller-like blades of a turbine around a rotor, which spins a generator, which creates electricity. The majority of wind turbines fall into two basic types - horizontal-axis turbines or vertical-axis turbines.

Horizontal-axis wind turbines have three blades and operate "upwind," with the turbine pivoting at the top of the tower so the blades face into the wind. Vertical-axis turbines are omnidirectional, meaning they don't need to be adjusted to point into the wind to operate.

Figure 2: Horizontal-axis turbine

Figure 3: Vertical-axis turbine

Unlike Solar PV installations, wind turbines can generate electricity at all hours of the day and night, providing that wind is available and as such, they provide greater opportunity in terms of when electricity can be generated.

Wind generation offers a far more consistent generation profile compared to solar and is better matched to co-location with heat generating plant due to the energy generation and heat consumption aligning relatively well. Wind energy projects have a higher risk of planning rejection compared to solar PV and this is a risk that is burdened by the developer, who must be willing to invest development money into planning, design, pre-construction works, grid connection and payments, fees and securities. Wind energy projects of the scale considered historically can take approximately five years to progress from design and planning to commissioning and this is dependent on numerous external factors such as planning contingencies and grid connection timescales, although the new Government has indicated that wind developments will be seen more favourably under their leadership. The largest barriers to wind are finding out if the local landowners are amenable to purchase/ lease of their land, the timescales and costs for acquiring a grid export connection and the acceptability to the local population.

Locations

From the constraints mapping exercise carried out following the site visit (contained within Appendix B), there are very few options for wind development in the surrounding area due to Nassington's location within a Green Infrastructure Corridor and the likely visual impacts on residential properties. While Mee Farm recommended a number of fields that they would consider suitable for wind energy development, and would be willing to host a wind turbine on, all Mee Farm owned land parcels are visible to the MOD radar at a height above 20m. There are also significant risks owing to the village's proximity to Peterbourgh Airfields (within the 5km safeguarding zone), position within Sibson Airfield's drop zone and position under the Wittering MATZ (Military Air Traffic Zone).

Land to the centre and north of Nassington has a slightly higher visibility to the MOD radar of 40m; however, from an aviation and radar perspective, a wind development does represent a significant risk.

Considerations

One of the main considerations is MOD coverage across Nassington. From analysis, it was noted that the proposed locations are subject to a MOD coverage of 20-40m above ground level; although this doesn't necessarily represent a showstopper since only one turbine is anticipated. However, the cost of implementation this technology does increase due to the requirement of MOD putting a 'blank' on their radar at the site.

Figure 4 overleaf shows existing, operational wind turbine developments in proximity to Nassington, overlaid with the MOD radar coverage maps, where the lighter the shade of red, the higher the limit.

Engagement with RAF Wittering and Sibson Airfield is underway to determine the likelihood of opposition to any turbine proposed within Nassington or the surrounding areas, and to obtain guidance from these two consultees as to any considerations that must be made for a turbine installation in relation to aviation and radar considerations. This report will be updated with feedback once received.

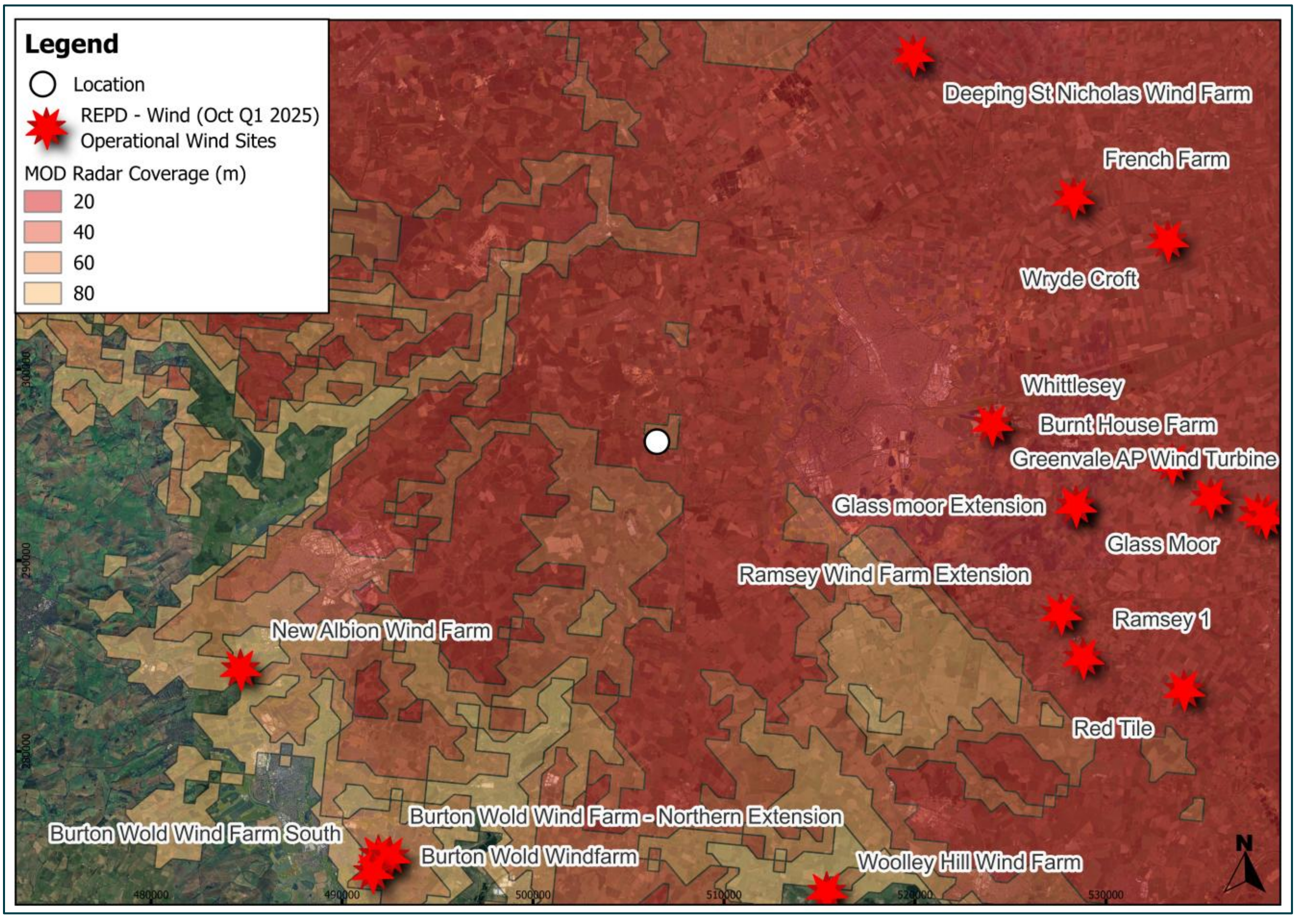


Figure 4: Existing wind energy developments in proximity to Nassington (white circle)

Additionally, wind turbines of smaller capacity (such as 500-750kW) could be explored as viable options if there is no scope for Nassington to be paid for exporting excess generation back to the grid. This may be more favourable in terms of planning and MOD with a reduced tip height.

3.2.3 Solar PV

Solar PV systems are either constructed as standalone, roof-top mounted systems (RMPV) which directly supply the building on which they are installed; or larger, ground mounted (GMPV) systems which could supply a number of buildings at any one time.

Figure 5: RMPV

Figure 6: GMPV

Recently, PV has been acknowledged as the best value per kWp renewable generation to install. As a proven technology, it is a reliable, low-risk and versatile option for renewable generation.

What must be considered in solar installations is its seasonal and daily variation in output. Figure 7 below illustrates an average daily generation profile of a 1MW solar array in summer and in winter. This is complimentary to commercial consumers, as they are generally more active in daylight hours; however, these variable profiles highlight the unlikeliness of 100% of a site's demand being met in real time with PV. This can be bettered with the installation of energy storage technologies, discussed subsequently.

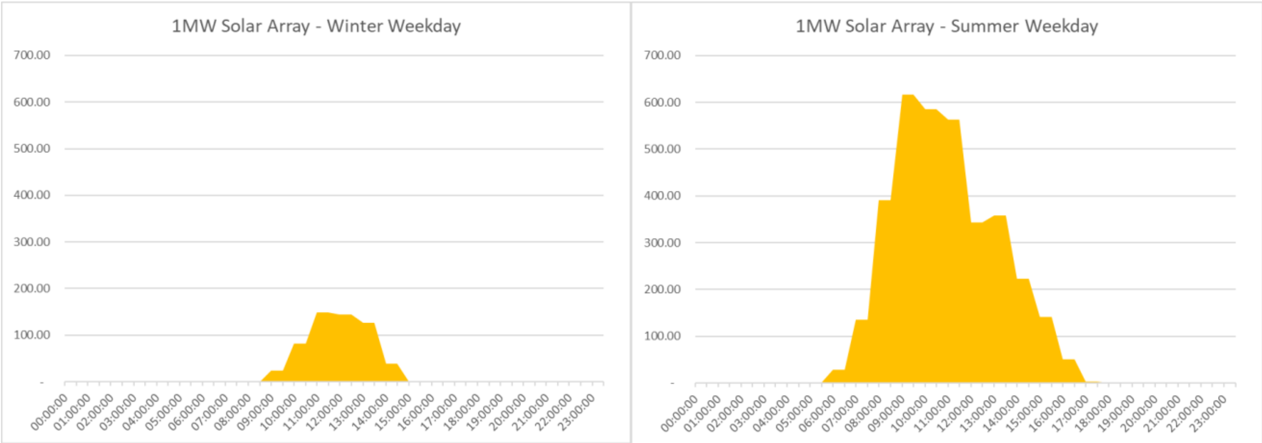


Figure 7: Summer vs Winter PV generation

The technology

Solar photovoltaic (PV) technology use cells made up of layers of semi-conducting material to convert sunlight into electricity. When light shines on the cell, it creates an electric field across the layers, causing electrons to flow, which in turn creates electricity. Cells are connected together to make modules (or panels), which are in turn connected together to form arrays. The solar PV arrays generated direct current (DC) electricity, which is then carried to an inverter which converts the DC to alternating current (AC) electricity – the same form of electricity that is delivered to buildings from a standard mains electricity connection.

The electricity can then be used directly to power to building or heat generating plant, stored in a BESS, or exported to the grid.

Benefits and constraints

The installation of a solar PV array can reduce annual electricity cost by offsetting the amount of electricity that needs to be purchased from the grid. A system can also reduce the carbon footprint of a scheme – solar PV generates electricity without emissions, whereas grid electricity has a much higher carbon footprint as it is made up of an energy mix from renewable sources, nuclear and conventional fossil fuel.

Solar systems are quiet and largely visually unobtrusive, particularly when installed sensitively on rooftops. Installation is a relatively quick and simple process and maintenance requirements are minimal once the system is installed.

Ultimately, solar energy is a locally available, renewable resource which cannot be depleted or altered. However, solar PV systems are limited by the available resource, and while modules will generate electricity on cloudy days or at lower light levels, the modules will only achieve maximum efficiency when it's very sunny and the sun is shining directly onto the panels. Trees or high buildings around solar arrays may cause shadows and shading across the array, which will also impact the amount of electricity generated, so careful consideration must be given to the location and design of the array.

Solar PV has the advantage over wind in that it is less contestable from a planning perspective due to it not being as visible from a far distance and does not have the same restrictions regarding proximity to residential property or other buildings. Design, construction, installation and commissioning of solar plants is considerably less complex than wind energy projects. Timescales for construction are therefore much shorter, though relies on achieving a grid connection. The land footprint for ground mounted solar PV is however much greater than wind. Land could be purchased or rented as part of a development opportunity and if this option presents an appealing option for the Client, then the landowner should be approached to gauge initial interest in the proposal. Locogen have extensive experience in engaging and negotiating with multiple landowners across renewable energy projects and are able to assist or lead in this regard, depending on NEAT's preference and level of established relationship.

One of the main drawbacks of solar PV is the seasonal variation in generation which results in poor generation over winter months, when the heat pump network is operating at its peak demand.

Locations

During the site visit, a number of agricultural fields were identified as being feasible for solar PV installations. These were evaluated against a number of typical development constraints, such as agricultural land class, glint and glare risk and residential amenity. The results of this analysis are contained in Appendix B.

3.2.4 BESS

The following characteristics should be considered when designing and selecting an energy storage technology:

1. Technology Readiness Level;
2. Scalability;
3. Response time;
4. Storage capacity;
5. Cost;
6. Round-trip efficiency;
7. Energy density;
8. Cycle life and calendar life; and
9. Environmental impact.

There are numerous ways to store electrical energy. Innovative methods, such as flywheels, hydro storage and gravitricity, are being developed as long term/high quantity energy storage. However, chemical energy storage (utilising batteries) is considered to be the most appropriate option for Nassington owing to the lower risks present from use of an established 'known' technology over innovative alternatives.

Four types of chemical BESS are considered:

- Lithium ion;
- Lead Acid;
- Flow; and
- Sodium sulphur.

Technology Readiness Level

Battery technology readiness level (TRL) is a measure of the maturity of a battery technology, indicating how close it is to being fully developed and ready for commercialization. The TRL scale ranges from 1 to 9, with 1 being the lowest level of maturity and 9 being the highest. The TRL scale is widely used in the battery industry and by government agencies to assess the readiness of battery technologies for different applications.

Below is a general overview of the different TRL levels and what they mean:

- TRL 1: Basic principles observed and reported;
- TRL 2: Technology concept and/or application formulated;
- TRL 3: Analytical and experimental critical function and/or characteristic proof-of-concept;
- TRL 4: Technology validation in laboratory environment;
- TRL 5: Technology validation in relevant environment;
- TRL 6: Technology demonstration in a relevant environment;
- TRL 7: System prototype demonstration in the designated environment;
- TRL 8: Actual system completed through test and demonstration; and
- TRL 9: Actual system proven through successful operations in the intended environment.

Battery technologies at TRL levels 1-3 are typically in the early stages of development, with limited experimental data or testing. Technologies at TRL levels 4-6 have demonstrated the feasibility and basic functionality of the technology in laboratory or relevant environments. Technologies at TRL levels 7-9 have demonstrated successful operation in relevant environments and are considered to be mature and ready for commercialisation.

It is important to note that the TRL scale is not a perfect indicator of commercial readiness, as different applications may have different requirements for technology maturity. For example, a battery technology that is considered to be at TRL level 8 for its designed application may not be ready for commercial deployment due to safety considerations.

Table 2: Technology readiness level[1]

Battery Name	Technology Readiness Level
Lead-acid batteries	9
Lithium ion batteries	9
Flow batteries	9
Sodium-sulphur batteries	7

Overall, Lithium ion batteries are currently the most widely used and mature technology for grid-scale energy storage, but other technologies like sodium-sulphur and flow batteries also have potential for certain applications.

Scalability

The scalability of large-scale batteries refers to their ability to be deployed in systems of various sizes to meet different energy storage needs. Here's how different large-scale batteries stack up in terms of scalability:

1. **Lead-acid batteries:** Lead-acid batteries are commonly used for small-scale applications, such as backup power for homes and small businesses, but can also be used in larger scale projects. Ultimately, lead acid batteries are not as scalable as Lithium ion batteries due to their limited energy density and shorter lifespan[2].

[1] A Comparative Review of Lead-Acid, Lithium ion and Ultra-Capacitor Technologies and Their Degradation Mechanisms (2022)

[2] Journal of Energy Storage: Characterizing different types of lithium ion cells with an automated measurement system (2016)

2. **Lithium ion batteries:** Lithium ion batteries are highly scalable and can be deployed in systems ranging from small residential applications to utility-scale projects capable of providing hundreds of megawatts of power. Their modular design allows for easy scaling up or down, depending on the energy storage requirements.
3. **Flow batteries:** Flow batteries are also highly scalable and can be deployed in systems ranging from small commercial applications to large utility-scale projects capable of providing multiple megawatt-hours of energy storage capacity. Their modular design enables easy scalability and allows for the addition of storage capacity as demand grows.
4. **Sodium-sulphur batteries:** Sodium-sulphur batteries are typically used in large-scale applications, such as grid-scale energy storage systems, and can provide several mega-watt hours of energy storage capacity. However, they are not as scalable as either Lithium ion or flow batteries due to their larger size and flexibility.

Although both flow batteries and Lithium ion batteries are both considered suitable in terms of scalability, Lithium ion batteries are generally considered to be more mature and more widely deployed than flow batteries. They have a higher energy density than flow batteries, which means they can store more energy in a smaller space. Lithium ion batteries are also known for their high round-trip efficiency, which means that they can discharge a large amount of energy quickly, making them a good choice for applications where rapid discharge is important.

Overall, Lithium ion batteries are the most scalable option for large-scale energy storage, while sodium-sulphur and lead-acid batteries are better suited for specific applications or projects on a smaller scale. While flow batteries are scalable from a technical perspective, the footprint required is substantially makes larger projects exceedingly challenging and expensive.

Response Time

Response time is the time it takes for a system to provide energy at its full rated power. The response time of large-scale batteries varies depending on the type of battery and the specific application. In general, the response time of a battery refers to how quickly it can provide or absorb power in response to a change in demand.

Lithium ion batteries are known for their fast response times and can deliver power quickly when needed. They are often used for applications that require quick response times, such as providing backup power to critical loads. Flow batteries, on the other hand, typically have slower response times compared to Lithium ion batteries. This is due to the fact that flow batteries require more time to ramp up or down their power output due to the need to adjust the flow rate of the electrolyte.

Lead-acid batteries have the slowest response time of an estimated 20-30 seconds, while sodium-sulphur batteries have the quickest response time of all four battery technologies, up to 1 millisecond.

Energy density

The energy density of a battery is an important factor to consider when selecting a technology for large-scale storage. In this section, there will be a comparison of the energy density of Lithium ion, flow, sodium-sulphur, and lead-acid batteries for large-scale storage applications. Energy density of the battery is effectively a function of the storage capacity and the batteries weight, meaning a battery with a low density will weigh a lot more than that of a high density and potentially require a much larger area to house the technology.

Lithium ion batteries have been widely used in large-scale storage applications due to their high energy density and efficiency. According to a study by the National Renewable Energy Laboratory (NREL), the energy density of Lithium ion batteries used for grid storage is 240+ Wh/kg[3]. However, the cycle life of Lithium ion batteries used for grid storage is much longer, with some batteries capable of lasting up to 20 years.

[3] Greening the Grid: Usaid Grid-Scale Energy Storage Technologies Primer (2021)

The energy density of flow batteries ranges from 10-50 Wh/kg[3], which is lower than the energy density of Lithium ion batteries. However, flow batteries have the advantage of being able to store energy for longer periods of time and can be recharged quickly, making them suitable for grid-scale energy storage.

The energy density of sodium-sulphur batteries ranges from 150-240 Wh/kg[3], which is lower than the energy density of Lithium ion batteries. However, sodium-sulphur batteries have the advantage of being able to discharge for longer periods of time than other battery types, making them ideal for applications that require long-term energy storage.

Lead-acid batteries have a lower energy density compared to other battery types, but they are inexpensive and have a long service life. The energy density of lead-acid batteries ranges from 30-50 Wh/kg[3], which is lower than the energy density of Lithium ion batteries. However, lead-acid batteries are still commonly used in large-scale storage applications due to their low cost and reliability.

Therefore, the energy storage capacity of a battery is an important factor to consider when selecting a technology for large-scale storage. While Lithium ion batteries have the highest energy density, other battery technologies such as flow batteries, sodium-sulphur batteries, and lead-acid batteries also have their own advantages for large-scale storage applications. Ultimately, the choice of battery technology depends on the specific requirements of the application.

Cost

Lithium ion batteries are currently the most commonly used battery technology for large-scale energy storage due to their high energy density and decreasing costs. Flow batteries and sodium-sulphur batteries are also being developed but currently have higher costs compared to Lithium ion batteries. Lead-acid batteries are the least expensive option but have lower efficiencies and shorter cycle lives.

The cost of Lithium ion batteries has been decreasing in recent years due to advancements in technology and economies of scale. According to a report by BloombergNEF[4] (BNEF), the cost of Lithium ion batteries for utility-scale projects in Europe were expected to drop by 68% between 2020 and 2050.

However, a more recent BloombergNEF[5] report in January 2023 found that the price of Lithium ion batteries increased by around 7% in 2022 led on by rising raw material and component prices. This was the first ever price increase in energy storage since 2010, and highlights the limited availability of materials and increasing geopolitical challenges.

Round-trip efficiency

Round-trip efficiency (RTE) in terms of battery storage technology is the percentage of electricity gathered by the technology that is later retrieved. A higher the round-trip efficiency means that less energy is lost in the storage process and vice versa. Energy is lost in operations such as charging, discharging and storage, making it impossible for a battery to ever be 100% efficient, however, there are some battery technologies that have a higher round-trip efficiency than others.

An indicative round-trip efficiency of different battery types is found in Table 3 below. Note that these are average estimates, and some models within specific technologies will perform better/poorer than this generalised average.

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[4] https://about.bnef.com/blog/energy-storage-to-steal-277b-from-power-grids-by-2050/

[5] https://about.bnef.com/blog/top-10-energy-storage-trends-in-2023/

Table 3: Comparison of battery storage efficiency levels[6]

Battery type	Round-Trip Efficiency
Lead-acid	80%
Lithium ion	95%
Flow	80%
Sodium-sulphur	90%

To maximise efficiency, batteries should be kept at room temperature, and sized correctly for their purpose, both to minimise self-discharge, and to prevent them being charged and discharged too rapidly. Many battery manufacturers will provide performance warranties on the basis that the battery does not exceed a set number of cycles per year, as the efficiency will degrade faster if the battery is charged and discharged too rapidly.

Cycle life and calendar life

Cycle life and calendar life are important factors to consider when evaluating the suitability of large-scale batteries for energy storage applications. Cycle life refers to the number of charge and discharge cycles that a battery can undergo before its capacity degrades to a certain level. Calendar life refers to the total lifespan of the battery, which is determined by the degradation of the battery's components over time, even when it is not being used.

Factors that reduce both a batteries cycle life and calendar life include how often the technology is used, the application it is used for and the conditions it is operating in. An example of this is that sodium-sulphur batteries require an operating temperature between 300-350°C; which is why they are best suited for stationary storage applications, any less than this would cause the battery to be inactive, while Lithium ion batteries can survive significant temperature changes with minimal repercussions.

One way to measure a battery's life-span is the average amount of cycles the battery undertakes before losing its performance. Cycles is a widely used term to count the number of full charges and discharges of a battery. This figure tends to be net and additive. For example, a charge of 100% is not required in one use. Instead, this could be through lots of smaller charges that all add up to 100% (i.e. one cycle).

Table 4: Battery storage technologies cycle life and calendar life[7]

Battery type	Cycles (average)	Years (Average)
Lead-acid	500-1,000	3-5
Lithium ion	1,000-3,000	10-15
Flow	1,500-14,000	5-20
Sodium-sulphur	2,500-4,000	10-15

The average lifespan of a lead acid battery is between 3-15 years (c. 500-1,000 cycles), while the average life expectancy of a Lithium ion battery is around 10-15 years (c. 3,000 cycles). Flow batteries generally have been found to have the longest average lifespan.

[6] Environmental and Energy Study Institute: Fast Sheet | Energy Storage (2019)

[7] Environmental and Energy Study Institute: 2023 Farm Bill Climate Side-by-Sides (2022)

Environmental impact

The environmental impact of large-scale batteries depends on a number of factors, including the specific type of battery technology, the materials used in their production, the energy sources used to manufacture and operate them, and the disposal or recycling methods used at the end of their life.

The extraction and refining of raw materials, as well as cell production, can have severe environmental effects, such as land degradation, biodiversity loss, creation of hazardous waste, or contamination of water, soil, and air. Unprofessional (or illegal) battery disposal can cause severe toxic pollution. This is a problem particularly within today's lead-acid battery value chain.

Lithium ion batteries can have environmental impacts, particularly in terms of the extraction of raw materials such as both lithium and cobalt. The extraction of theses minerals requires large amounts of water and energy. Additionally, the disposal of Lithium ion batteries can create environmental hazards due to the chemicals and heavy metals they contain.

Flow batteries typically use fewer toxic materials than other types of batteries and can be considered the most environmentally friendly of battery options. However, they still utilise large amounts of materials and they can require large amounts of land to operate due to their low energy density.

Sodium-sulphur batteries have the potential to be more environmentally friendly than Lithium ion batteries because sodium is more abundant and easier to extract than lithium. However, sulphur is a toxic chemical and if not managed properly can pose a risk to the environment.

With regards to lead-acid batteries, production and disposal of lead-acid batteries can have significant environmental impacts due to the lead and sulfuric acid they contain. Lead is a toxic heavy metal that can contaminate soil and water, while sulfuric acid can cause acidification of waterways. Proper disposal and recycling methods are critical to minimizing the environmental impact of lead-acid batteries.

Fire risk

More recently, fire prevention and suppression has been at the forefront of concerns for Lithium ion batteries. While much has been done to prevent the propagation of battery fires, there is a crucial concern with regards to the toxic fumes that are emitted when/if a Lithium ion battery catches fire. While this is also the case for sodium sulphur and lead acid batteries, the prevalence of Lithium ion means that more incidents have occurred with this technology.

Generally, Lithium ion and Sodium sulphur batteries have significant fire risk; Lead Acid batteries have a low fire risk, and flow batteries generally have no fire risk associated with the battery itself. There is, however, significant mitigation and numerous standards in place to prevent and suppress fires should they occur.

Summary

Table 5 below shows a comparison between battery storage technologies compiling the factors discussed above.

Table 5: Battery comparison

Battery type	TRL	Life expectancy	Cycles	Efficiency	O&M Costs
Lead-acid batteries	9	3-15 years	500-1,000	80%	£8/kW
Lithium ion batteries	9	10-15 years	1,000-3,000	95%	£8/kW
Flow batteries	7	5-20 years	1,500-15,000	80%	£12/kW
Sodium-sulphur batteries	9	10-15 years	2,500-4,000	90%	£23/kW

With regards to which battery technology is favoured over any other, lead acid batteries have the least potential due to their short cycle and calendar life, however, are among the cheapest of the battery technologies.

Flow batteries have the longest potential with cycle and calendar life, however, have the lowest efficiency with a high cost.

Sodium-sulphur batteries end up having a high efficiency and a high calendar life with a good cycle life, although, have the highest cost associated with operations, while also being required to being stored between 300-350°C.

Lithium ion batteries have the same expected calendar life as Sodium-sulphur batteries but unfortunately do not have the same potential of cycle life, this is made up however by having the highest efficiency with the lowest cost.

Advantages and Disadvantages

Table 6: Advantages and disadvantages of different battery types[8]

Battery type	Advantages	Disadvantages
Lead-acid batteries	• Low cost; • High efficiency; • High recycled content.	• Low energy density; • Short lifespan; • Limited depth of discharge; • High environmental impact.
Lithium ion batteries	• High energy density; • Long lifespan; • Less environmental impact.	• High material demand; • Shorter lifetimes in larger scale projects.
Flow batteries	• High efficiency; • Long lifespan; • Less environmental impact.	• High costs; • Low energy density; • Requires high maintenance.
Sodium-sulphur batteries	• High energy density; • High efficiency; • Long lifespan.	• High initial cost; • Toxic materials; • Safety issues.

Conclusions

A Lithium ion energy storage system offers several advantages over other types of energy storage systems. Firstly, Lithium ion batteries have a lower risk of fire compared to other battery chemistries, such as lead-acid batteries, due to their superior thermal stability and safety features. Secondly, procurement of Lithium ion batteries is relatively easy as they are widely available in the market. Additionally, with the increasing demand for energy storage systems, many local manufacturers are now producing Lithium ion batteries, which can lead to a reduction in lead times. These factors make Lithium ion energy storage systems a compelling option for Nassington where looking to implement an energy storage solution to complement local generation.

[8] Sustainable Energy Technologies and Assessments: Life cycle assessment of lithium-ion batteries and vanadium redox flow batteries-based renewable energy storage systems (2021)

Lithium ion was deemed the most suitable BESS technology for the NEAT project due to the availability of the BESS as an existing 'proven' technology, teamed with the environmental impact and safety issues of alternatives. Lithium ion also has a good track record given that the majority of existing projects within England are Lithium ion-based.

BESS team: Add conclusions relevant to NEAT and this project.

3.2.5 Sand Batteries

During the course of a previous project, Locogen worked with a community group who were able to meet with a Finnish company looking to develop an innovative thermal store arrangement using wet sand heated to high temperatures through electricity. If the community was able to generate electricity through their own sources, it was asked if Locogen could model if this approach could be a viable alternative to either of the heat network options considered to date.

In principle, the idea is that wet sand has a good thermal mass and can be heated up through resistive elements charged by electricity. The Finnish design refers to temperatures in excess of 600 degrees, which would result in the boiling of the water and a volume/pressure issue that would need to be considered but would benefit from additional energy release from phase change.

Locogen is unable to model the state change element but has modelled the thermal storage capacity and the energy charge/discharge process to understand if the timing and proportion of the generation is suited to the demand requirements.

In order for the sand heat battery system to work, there are two methods that were considered:

- The first is where the system operates at high temperature and provides heat to each of the houses based on the stored energy. This system would be comparable to the 'hot' DHN network systems. This required the store to maintain a temperature above the end user secondary distribution temperature (minimum 70°C). Additionally, it must include for the energy loss in the distribution network.
- Alternatively, a scenario was modelled considering a hybrid arrangement where the thermal store could be used in place of the ground array as the source of low temperature heat for the low temperature network. As the temperature within this rises, the SCOP of the individual heat pumps would rise, requiring less and less electricity to be put into the heat pumps directly. The maximum low temperature input for most heat pumps is 25°C so this was used for the outlet temperature (although this could be explored in more detail if still of interest during the detailed feasibility/development stage of the project).

For the previous project, both models were tested using the hourly generation and thermal consumption profiles used for the other network analysis. However, given the complexity of reaching a stable thermal condition in the heat store the model was modelled over a five year period.

The results of the modelling were that it was technically feasible to use either method, but the limitation is either the size of generation required, or the capacity of the heat battery required.

For the high temperature network, a stable system was achieved after approximately 3 years, but required approximately 10MW of solar PV and a thermal store of in excess of 5,000 tonnes of wet sand (2,500m^3). To achieve this with less PV would require higher proportions of grid import to directly heat the network and keep the heat battery from the grid. When modelled, a PV array of below 3MW would require more electrical energy to be imported than the total energy delivered to the houses (due to the network loss) meaning that this solution would be more expensive to operate than heating each house directly with electricity. On this basis, using this model, this idea cannot be taken forward. However, given the innovative nature of this proposal, Locogen did not claim that the model produced was a comprehensive analysis of the situation.

For the low temperature, shared loop, network approach, if a PV array of around 5MW was available, by maintaining the heat store at a lower temperature and allowing the water to circulate at around 25°C, the annual SCOP of the heat pumps was increased to 5.9 (from c.3), resulting in a reduction in electricity consumption of around half. There were a number of periods where the heat store dropped below freezing so it would have been necessary to supplement this with some boreholes. At the stage of analysis, the CAPEX of the additional thermal storage infrastructure was unknown so a full economic evaluation could not be undertaken. It was clear however that a hybrid model where generation is combined with some form of thermal storage to utilise the surplus generation from the PV could be more cost competitive than exporting it to the grid.

Locogen have re-run this analysis at the request of NEAT using publically available information on the dry sand Polar Night battery installed in Finland and have determined (at a very high level, recognising that Polar Night is a demonstrator project only) that the economics of this system wouldn't be vastly different from the information set out earlier.

The project would still require the heat network and the renewable energy generation, as well as the plantroom, and some form of backup boiler. There would be potential to reduce or remove some of the plant, but there would also be a requirement to construct a large tank (c. 12m high) filled with sand. While the Polar Night solution is interesting, only one has currently been constructed, with a second planned, which points to a level of associated risk with investment in innovative technologies.

4. ENERGY DEMAND AND DESIGN CONSIDERATIONS

Following on from the information gathered through the distributed energy survey, Locogen has carried out an analysis to estimate the energy demands and assess the compatibility with connection to a district heating network. Energy Performance Certificates (EPCs) were also used to provide an initial estimate of energy demands.

In conjunction with the survey data received, EPCs were used to extract the space and hot water heating demands of the available properties; where there were no EPCs present for properties, EPCs for dwellings of similar footprint and construction were used. Local climate data (average external temperature and degree days) was then used to determine peak heat loads for each property. It was assumed that hot water is heated twice a day, one hour each time to establish hot water peak load. The calculated demands that are the basis for this report are summarised in Table 7 below.

Table 7: Calculated demands & loads for Nassington

Item	Value
Buildings under review	369
Total space heating demand	3,734,092 kWh
Total hot water demand	718,657 kWh
Total heating and hot water demand	4,452,749 kWh
Peak load	1,996 kW

4.1 Future demands

As discussed in Section 1.2, Nassington's draft neighbourhood plan makes provision for 41 new dwellings in Nassington between 2021 and 2031, across two sites, alongside a new community 'hub' to replace the village hall.

These buildings will be required to be constructed in line with the Building Regulations (currently under Conservation of fuel and power: Approved Document L) for building performance, with minimum standards for building fabric and electrical/mechanical plant performance.

As future targets for building performance cannot be estimated, in the development of a 'future' energy profile, these 41 new dwellings and the community hub have been assumed to have a building performance in line with the dwellings on Fenn Close, which are the newest buildings to be constructed in Nassington. This represents a 'worst case' demand profile, as it is anticipated that buildings will be required to perform better as revised iterations of the Building Regulations are published over the next decade.

Electric vehicle charging

From the survey responses received, 11 out of 50 responses (or 22%) confirmed that they would be looking to install an electric vehicle charger in the next 12 months to 5 years. Thirteen respondents confirmed that they already have an EV charger. Assuming that this acts as a representative sample of Nassington, this suggests that 96 properties already have electric vehicle chargepoints, with 82 properties planning to install a chargepoint within the next 5 years. It has been assumed that each of the 41 new dwellings and the community hub will be fitted with a chargepoint.

Domestic charge points have a typical peak load of 3.6kW (16A) or 7kW (32A).

Diversity on EV charging to be agreed with NEAT for future demand profile (i.e. how many people are actually charging at any one time?).

Strategy for communal EV charging for those who live streetside and have no space for EVCP to be agreed with NEAT.

4.2 Network energy demand

Locogen have considered the applicability of both centralised and shared loop heat network options for this project. Due to the requirement of connecting older properties to the network that currently have boilers that operate at high temperatures, a 4th generation network is considered to be the most appropriate when exploring a centralised energy centre option. For shared/ ambient loop option, a 5th generation network is best suited in order to utilise the higher efficiency.

Centralised (high temperature) heat network

Centralised (high temperature) networks are typically phased in construction by connecting initial anchor loads, which have the greatest demands first. Properties that are passed by pipework enroute to principal anchor loads can then be connected once the network is established. The network can then be expanded in phases incorporating more buildings/ properties, once confidence in the operation of the network is high, costs and risk reduced and there is sufficient heat capacity from the source(s).

The calculated summary of high temperature heat pump systems is noted in Table 8 below. This takes into account the peak heat loss, domestic hot water (DWH), pipe network and associated heat losses within the network pipe.

Figures in Table 8 assume that a ground source heat pump is used at the energy centre to generate heat.

Table 8: Centralised heat pump network summary

Item	3rd Generation	4th Generation
Network length	c.8,000 m	c.8,000 m
Heat delivered	4,920,903 kWh	
DHW delivered	735,711 kWh	
Heat loss in network pipe	5,656,614 kWh	1,414,154 kWh
Total annual network demand (thermal)	11,313,228 kWh	7,070,768 kWh
Seasonal coefficient of performance (SCOP)	4.8	4.8
Annual electrical demand	4,094,681 kWh	2,559,176 kWh

Ambient loop heat pump system

The calculated summary of an ambient loop heat pump system is noted in Table 9 below. This takes into account the peak heat loss, domestic hot water (DWH), pipe network and associated heat losses within the network pipe. Electrical demand is the total electrical demand required by each property to run their own individual heat pump.

Table 9: Ambient loop heat pump network summary

Item	Value
Heat delivered	4,920,903 kWh
DHW delivered	735,711 kWh
Heat loss in network pipe	0 kWh
Total annual network demand (thermal)	5,656,614 kWh
Seasonal coefficient of performance (SCOP)	4.8
Annual electrical demand	2,047,341 kWh

Stand-alone ASHP

The calculated summary of stand-alone heat pump systems is noted in Table 10 below. This assumes that rather than running a district heat network through Nassington, each property is fitted with an individual air source heat pump.

Table 10: Stand-alone heat pump summary

Item	Value
Average space heating demand	10,376 kWh
Average hot water demand	1,996 kWh
Average total demand (thermal)	12,372 kWh
Range of heat pumps required (peak thermal capacity)	5 – 42 kW
Seasonal performance factor (SPF)	2.7
Range of heat pumps required (peak electrical capacity)	2 – 15 kW

It should be highlighted that while Locogen acknowledge that heat loads differ in each property with some larger than the average (ranges from 5kW to 42kW), it would be beyond the scope of this project to assess each property and the demands individually, therefore when referring to individual systems, estimated costings will be given based on per kW of plant required.

4.3 Electricity

4.3.1 Overview

It has been shown through the previous analysis that in the case of either a hot or ambient loop network, a considerable amount of electrical energy is required to operate the networks. With the aim of decarbonising the heating within Nassington, it would be prudent to assess opportunities for onsite or nearby renewable energy generation to supply the village with renewable electricity which can then be used either directly for power or for provision of thermal energy required for the buildings – not only could this reduce operational costs but also a degree of energy independence with the community able to own both the generation as well as consumption assets.

The study will also consider a wind turbine, or turbines, or ground mounted solar PV to aid with electric demand from the heating technologies. The solutions set out herein are proposed to maximise on-site usage of electrical generation, with surplus to be exported to the national grid.

4.3.2 Technology options – Solar PV

A 2MW solar PV array was identified as the most suitable size for a ground mounted PV array, as it could easily be located on six out of the seven sites reviewed. Solar developments smaller than 5MW are generally most suitable for community groups to build, own and operate as they represent a scale that generates higher amounts of electricity, but are not so large to incur substantial transmission upgrade costs and unachievable CAPEX figures.

Figure 8 below shows the generation profile for a 2MW solar PV ground array in Nassington, with Table 11 providing an overview of the electricity generated.

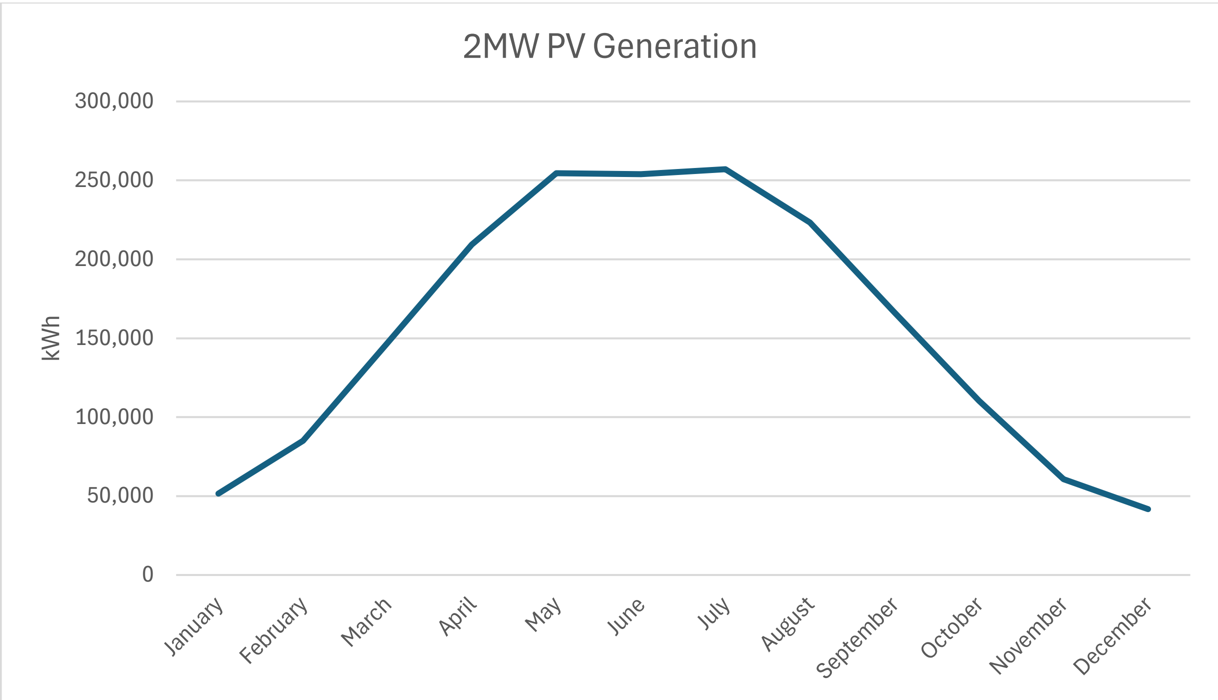


Figure 8: Generation profile for a 2MW solar PV array in Nassington

Table 11: Proposed Solar PV summary

Item	Value
Size of solar array (MW_{DC})	2
Electrical capacity per panel (W_{DC})	550
Anticipated annual yield (MWh)	1,860

4.3.3 Technology options – Wind

For this assessment, a 1 MW wind turbine generator (as shown in Table 12) was modelled. Turbines at this scale are typically harder to come by as the market moved to focus on much larger multi-megawatt machines for offshore use; however, many companies have begun to sell reconditioned/refurbished turbines at this scale which have lower CAPEX costs.

Figure 9 below shows the generation profile for a 1MW wind turbine in Nassington, with Table 12 providing an overview of the electricity generated.

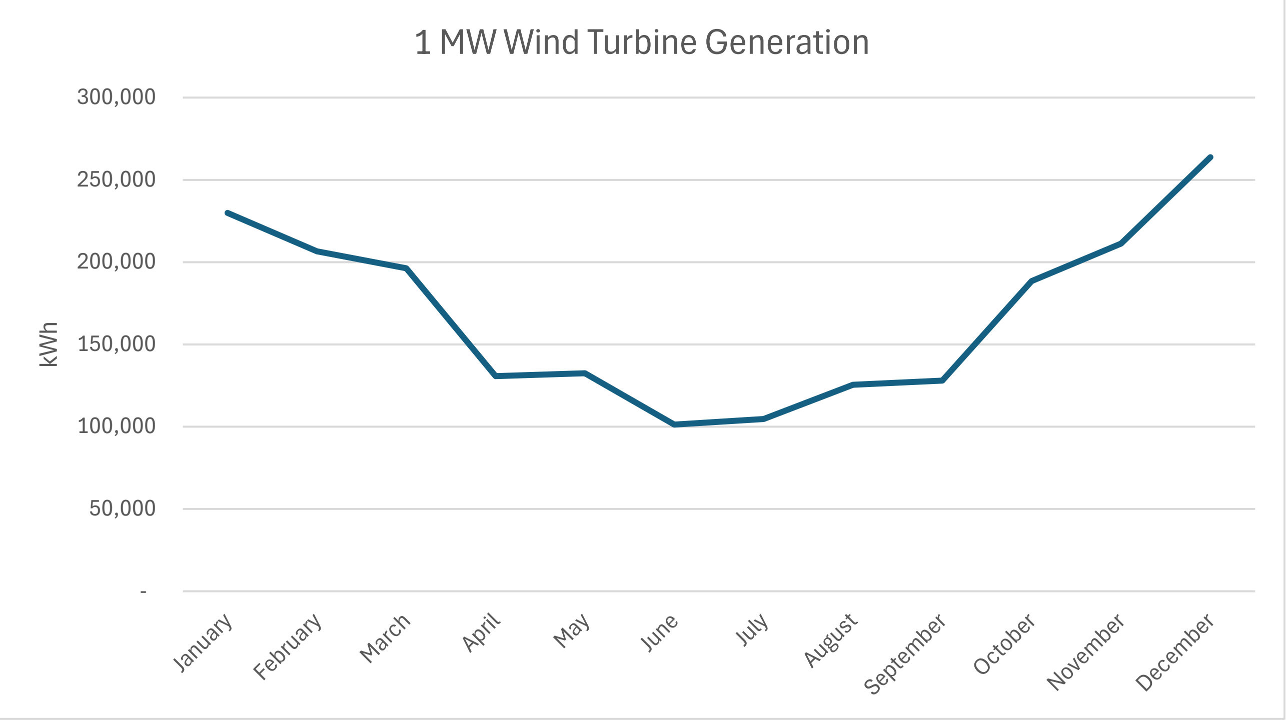


Figure 9: Expected generation profile for a 1MW wind turbine in Nassington over a 1 year period

Table 12: Proposed wind turbine summary

Item	Value
Capacity of wind turbine (MW)	1
Hub height (m)	46
Tip height (m)	76.5
Anticipated annual electricity yield (MWh)	2,019

4.3.4 Technology options – comparison

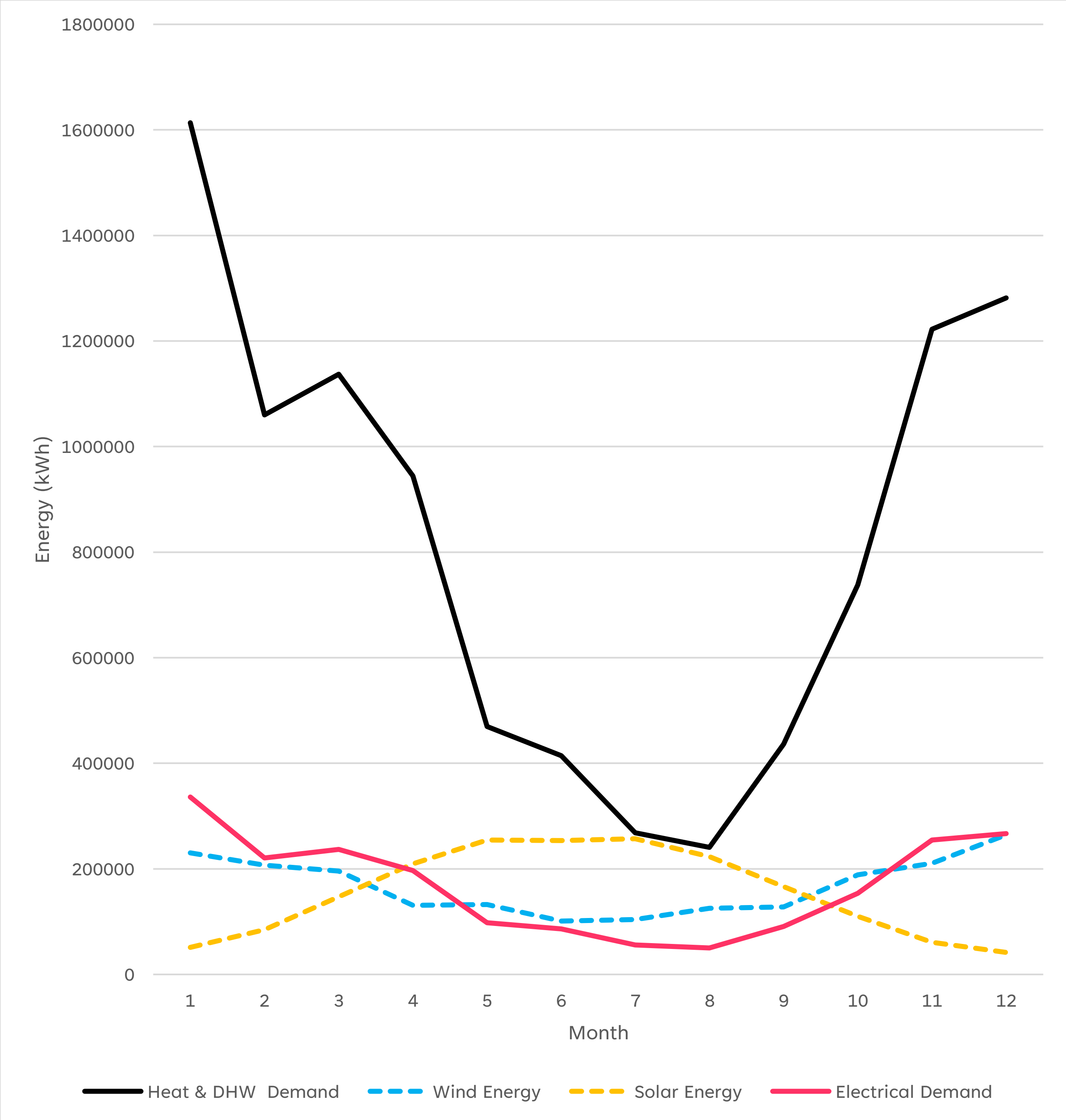


Figure 10: Comparison between heat/DHW demand, electrical demand, wind and solar PV generation

Figure 10 above demonstrates how the heating and domestic hot water (DHW) demand better matches the generation from a wind turbine, as opposed to a solar PV array. The total heat energy demand is lower in summer, when properties require less heating, but higher in winter when heating demand is vastly increased. The electrical demand has been calculated from the electrical input to a ground source heat pump to meet the heat and domestic hot water demand.

Solar PV generation is vastly increased in summer due to longer days and sunnier conditions, and therefore generates the majority of the annual demand during these months. The excess electricity generated would be required to be stored on site, exported to the grid, or exported via private wire to an/a number of offtaker(s).

5. ENERGY FLOW MODELLING

Energy flow modelling has been undertaken for the three different types of heat network under consideration at Nassington (high temperature 3rd and 4th generation networks, and ambient loop), with the two different electricity generation options (1MW wind turbine and 2MW solar PV array) overlaid.

The energy flow model shows the flow of energy through time, and in these graphs, the following elements are shown:

- The thick black line at the top of the graph shows the total electricity demand (the annual electricity used by the heat pumps to create heat for distribution through the heat network, or in the case of ambient loop, the electricity required village wide to supply each properties' heat pump).
- The blue section, which shows the electricity required to be imported from the grid to meet the total electricity demand.
- The green section, which shows the electricity used directly from the generating plant (i.e. electricity used directly as the turbine/solar PV is generating) to meet the total electricity demand.
- The red section, which shows the excess electricity generated which is exported to the grid (i.e. when more electricity is being generated than is required by the heat pump).

The following scenarios have been modelled:

- Scenario 1: 3rd generation high temperature heat network with a 1MW wind turbine
- Scenario 2: 4th generation high temperature heat network with a 1MW wind turbine
- Scenario 3: ambient loop heat network with a 1MW wind turbine
- Scenario 4: 3rd generation high temperature heat network with a 2MW GMPV array
- Scenario 5: 4th generation high temperature heat network with a 2MW GMPV array
- Scenario 6: ambient loop heat network with a 2MW GMPV array

5.1.1 Scenario 1: 3rd generation high temperature heat network with a 1MW wind turbine

Table 13: Energy flow model outputs (3rd generation DHN + 1MW wind)

Description	Value (kWh)	Percentage
Total annual generation	2,072,616	-
Generation used on site	1,259,095	61%
Generation exported to grid	813,520	39%
Total demand	4,094,681	-
Total annual site demand met	1,259,095	31%

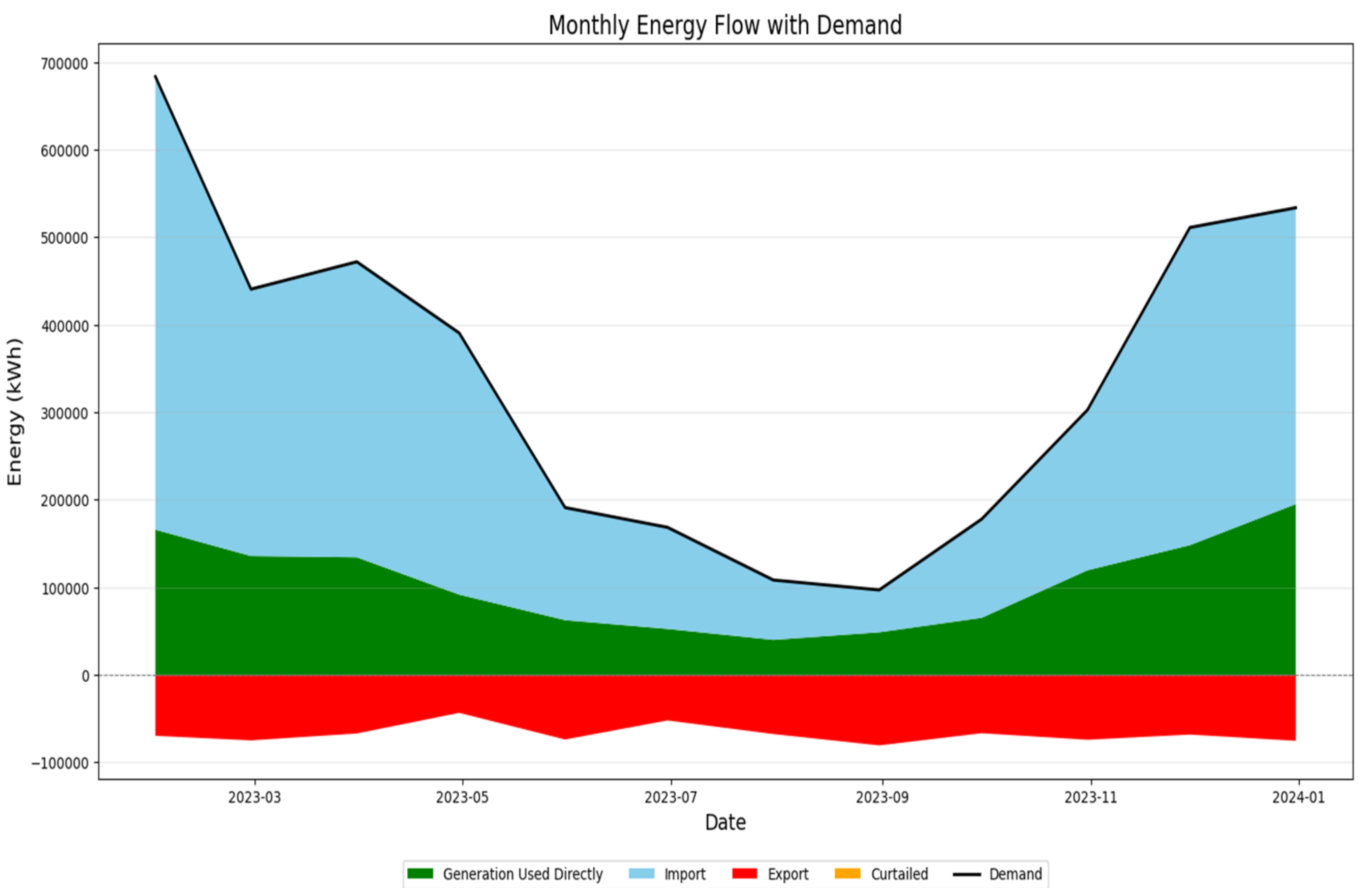


Figure 11: Energy flow model graph (3rd generation DHN + 1MW wind)

5.1.2 Scenario 2: 4th generation high temperature heat network with a 1MW wind turbine

Table 14: Energy flow model outputs (4th generation DHN + 1MW wind)

Description	Value (kWh)	Percentage
Total annual generation	2,072,616	-
Generation used on site	1,086,552	52%
Generation exported to grid	986,063	48%
Total demand	2,559,176	-
Total annual site demand met	1,086,552	43%

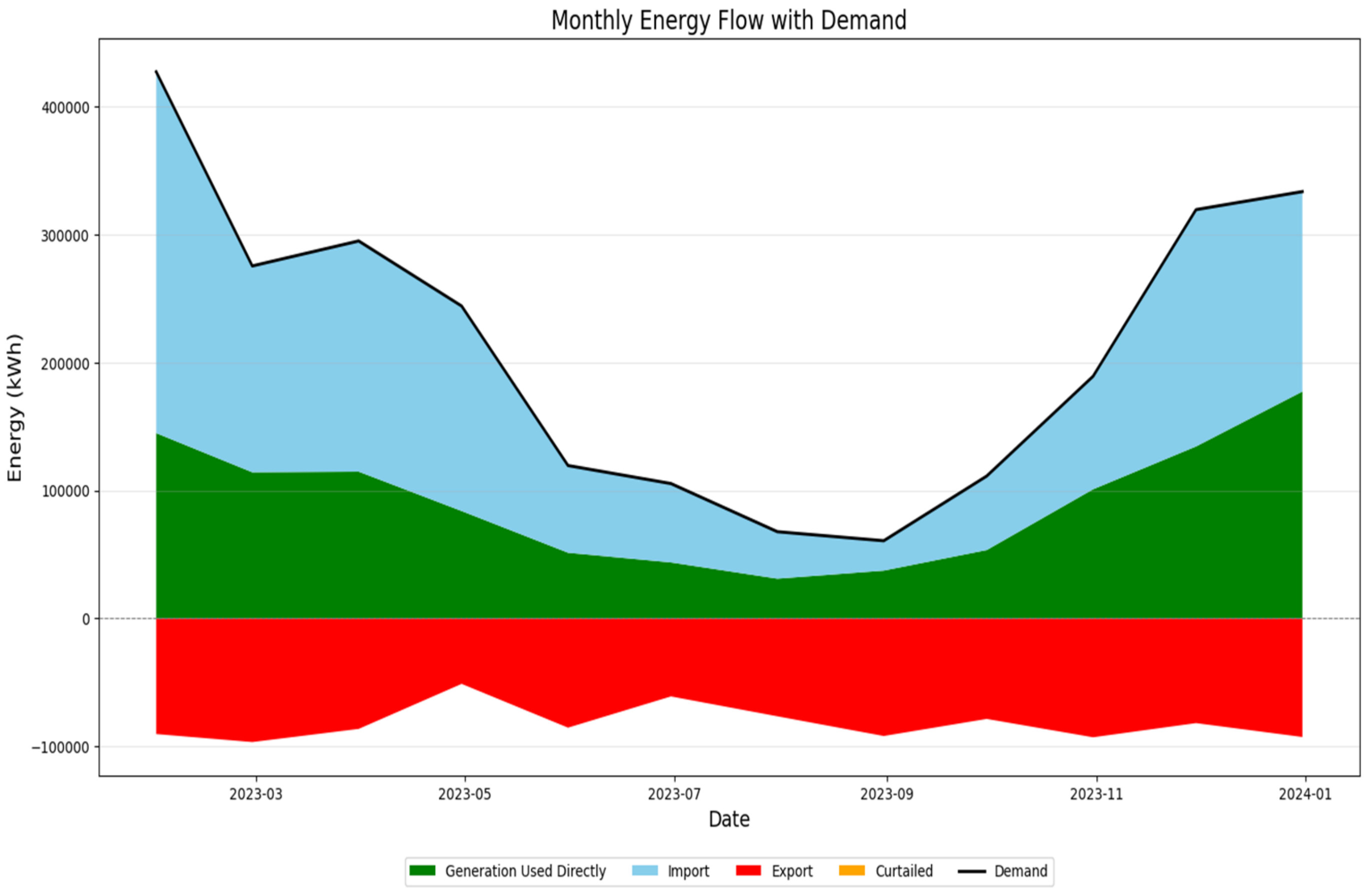


Figure 12: Energy flow model graph (4th generation DHN + 1MW wind)

5.1.3 Scenario 3: ambient loop heat network with a 1MW wind turbine

Table 15: Energy flow model outputs (ambient loop DHN + 1MW wind)

Description	Value (kWh)	Percentage
Total annual generation	2,072,616	-
Generation used on site	981,759	47%
Generation exported to grid	1,090,856	53%
Total demand	2,047,341	-
Total annual site demand met	981,759	48%

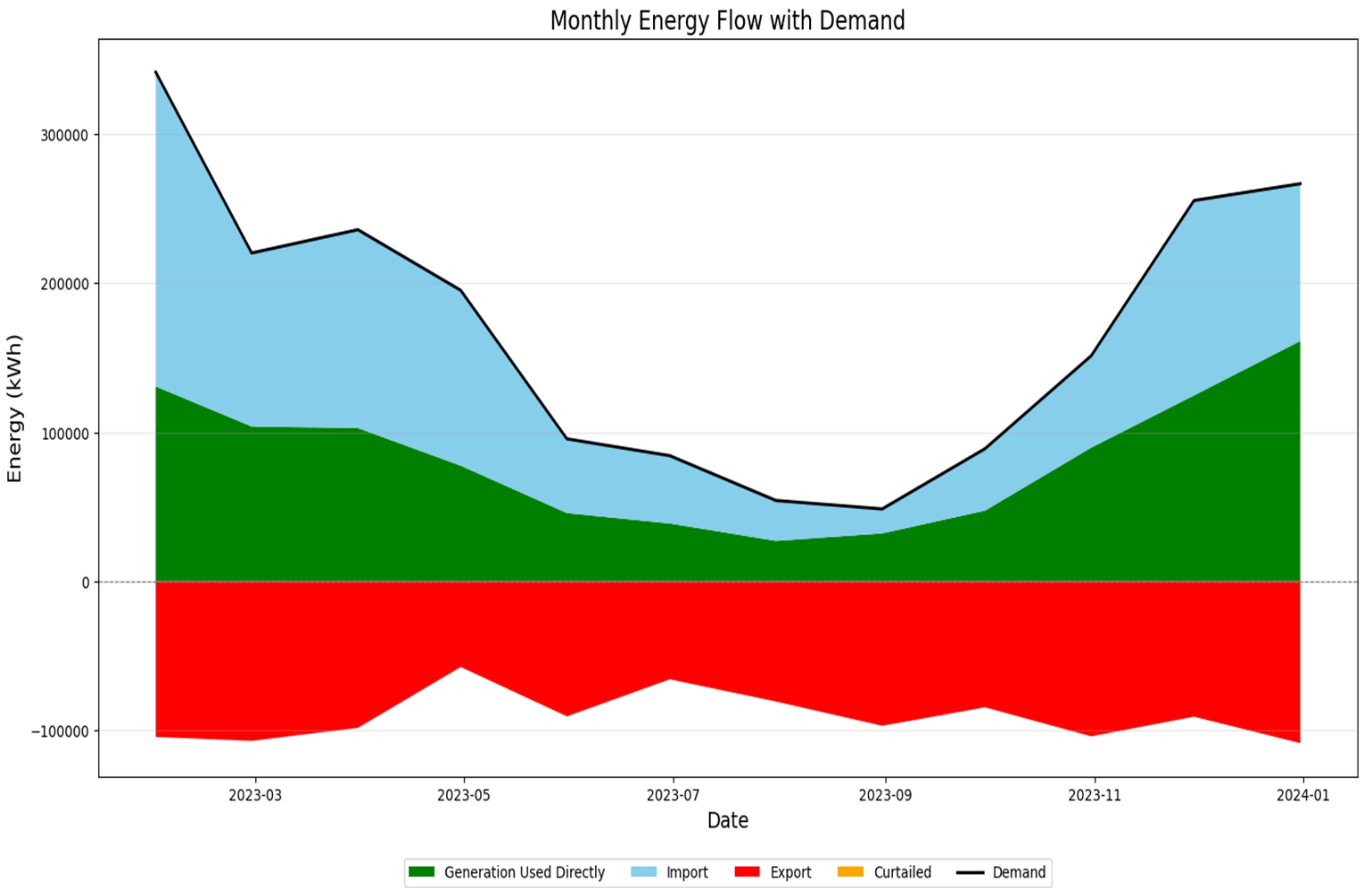


Figure 13: Energy flow model graph (ambient loop DHN + 1MW wind)

5.1.4 Scenario 4: 3rd generation high temperature heat network with a 2MW GMPV array

Table 16: Energy flow model outputs (3rd generation DHN + 2MW solar PV)

Description	Value (kWh)	Percentage
Total annual generation	1,860,711	-
Generation used on site	483,151	26%
Generation exported to grid	1,377,560	74%
Total demand	4,094,681	-
Total annual site demand met	483,151	12%

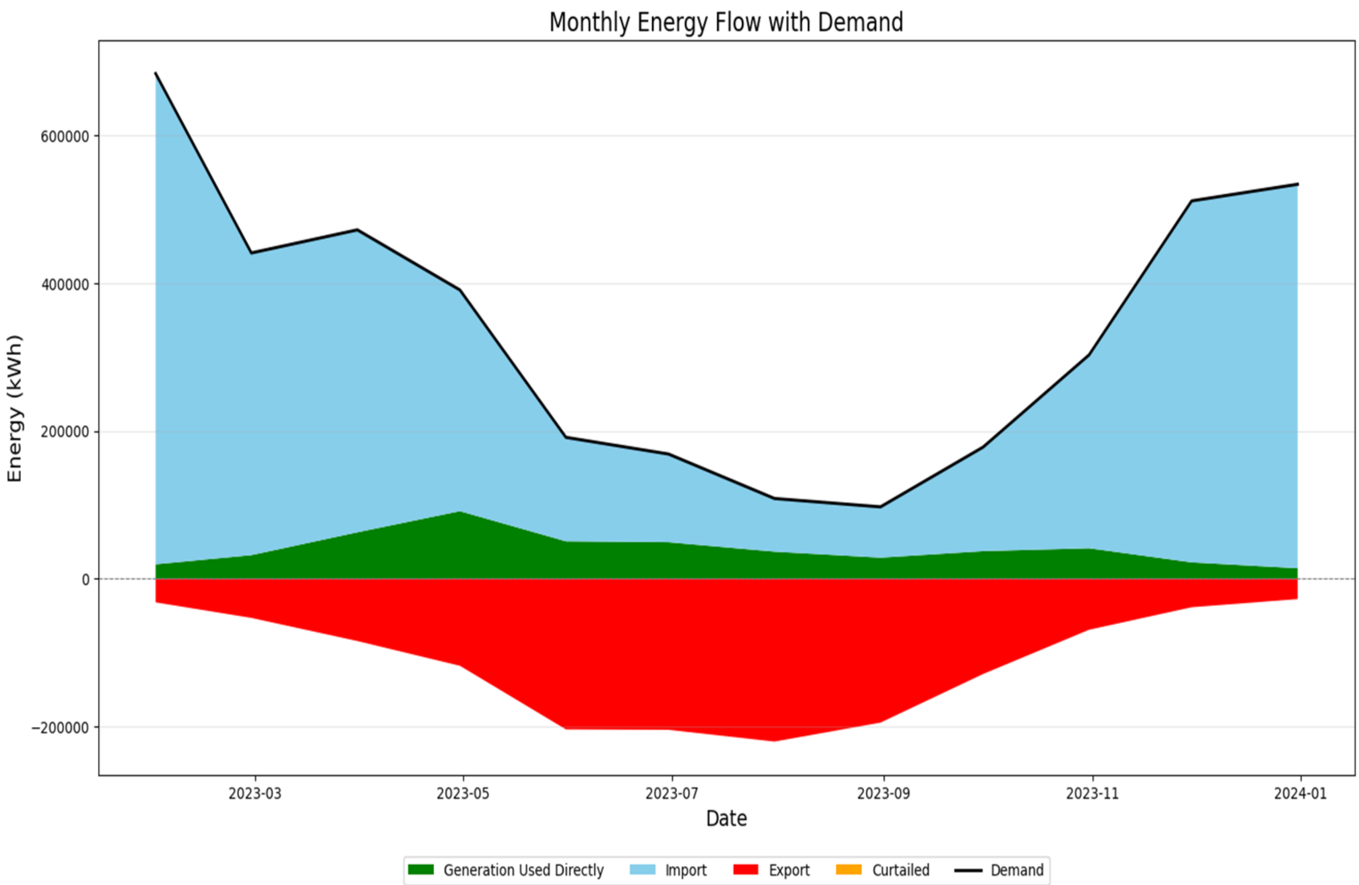


Figure 14: Energy flow model graph (3rd generation DHN + 2MW solar PV)

5.1.5 Scenario 5: 4th generation high temperature heat network with a 2MW GMPV array

Table 17: Energy flow model outputs (4th generation DHN + 2MW solar PV)

Description	Value (kWh)	Percentage
Total annual generation	1,860,711	-
Generation used on site	372,773	20%
Generation exported to grid	1,487,938	80%
Total demand	2,559,176	-
Total annual site demand met	372,773	15%

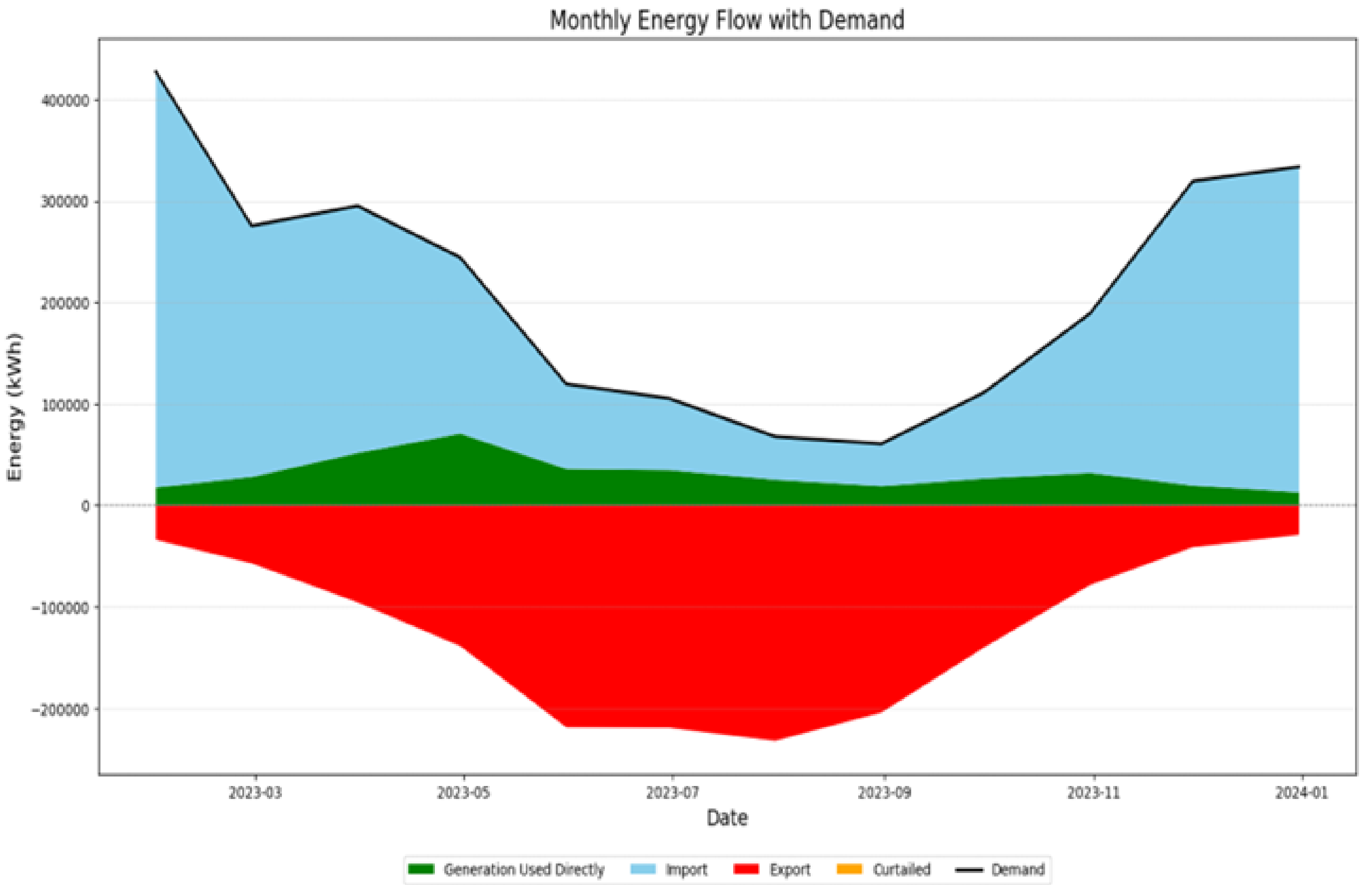


Figure 15: Energy flow model graph (4th generation DHN + 2MW solar PV)

5.1.6 Scenario 6: ambient loop heat network with a 2MW GMPV array

Table 18: Energy flow model outputs (ambient loop DHN + 2MW solar PV)

Description	Value (kWh)	Percentage
Total annual generation	1,860,711	-
Generation used on site	324,603	17%
Generation exported to grid	1,536,108	83%
Total demand	2,047,341	-
Total annual site demand met	324,603	16%

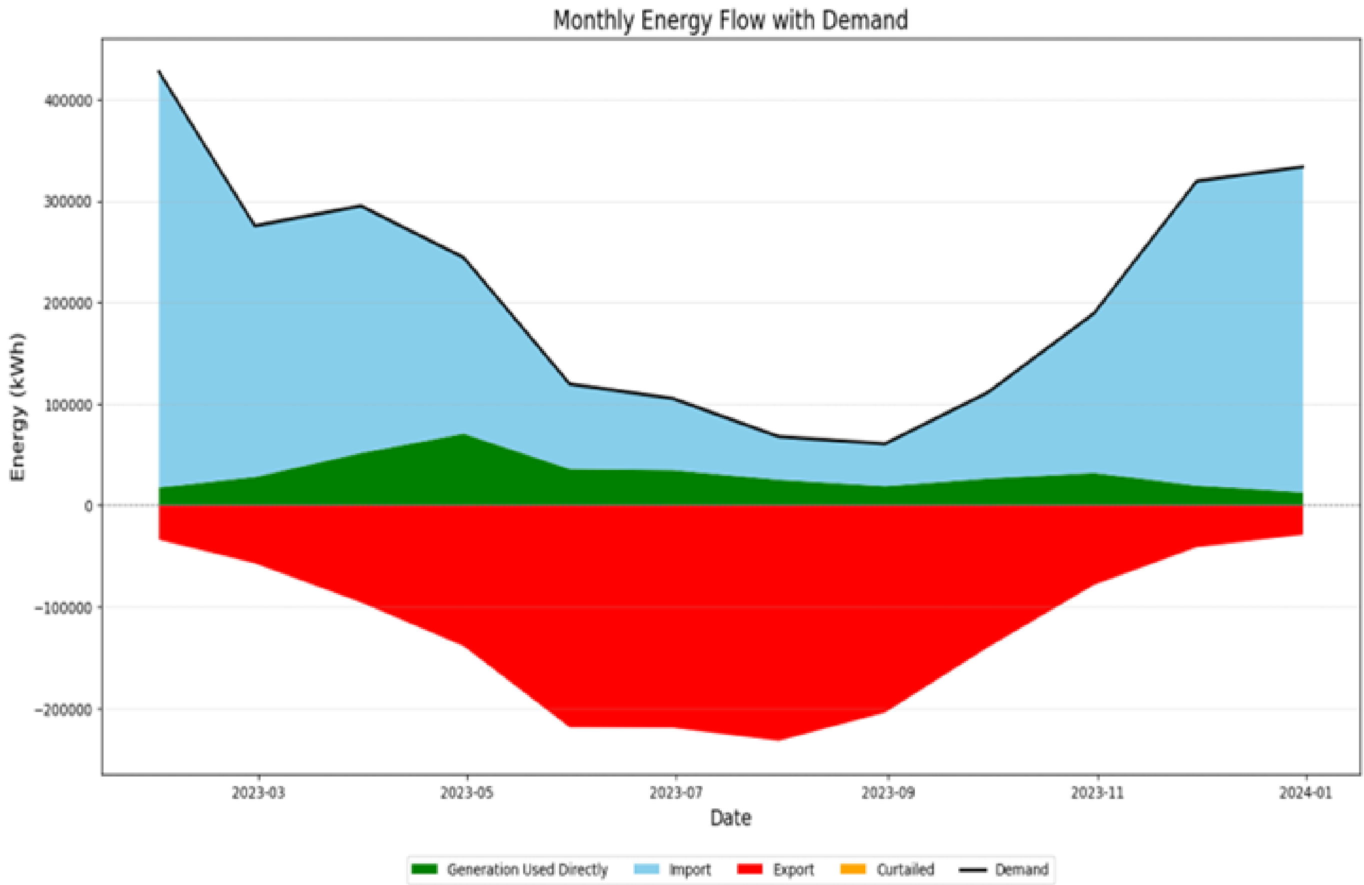


Figure 16: Energy flow model graph (ambient loop DHN + 2MW solar PV)

5.2 Findings

As shown in the energy flow model results above, the co-location of wind with heat generating plant is, on the whole, more suitable. This is due to the higher wind resource in winter months pairing well with the higher heat demand in October to March.

For an ambient loop system paired with a 1MW wind turbine, almost 50% of the electricity required is met by electricity generated on site; however, this assumes that the turbine is connected by private wire to all properties connected to the ambient loop network.

In contrast to this, less than 20% of the electricity demand required to run any of the heat network options is met by a 2MW solar PV array, with the vast majority of the electricity generated exported to the grid.

6. PLANNING, PERMITS AND CONSENTS

The following section explores the different planning, permitting and consenting requirements for the different technologies discussed in Section 2 with regards to the installation of renewable energy technologies within Nassington.

6.1 Roof mounted solar PV

For properties outwith the Nassington Conservation Area, solar PV installations of up to 1 MWp capacity (for non-domestic buildings), planning permission is not required, as per Schedule 2, Part 14 of the Town and Country Planning Order 2015.

The Permitted Development order stipulates that solar PV can be installed on the roof of a non-domestic building, subject to the condition that an installation is sited "so as to minimise its effect on the external appearance of the building and the amenity of the area" and the following exclusions:

> "(a)the solar PV equipment or solar thermal equipment would be installed on a pitched roof and would protrude more than 0.2 metres beyond the plane of the roof slope when measured from the perpendicular with the external surface of the roof slope;
>
> (b)the solar PV equipment or solar thermal equipment would be installed on a flat roof, where the highest part of the solar PV equipment would be higher than 1 metre above the highest part of the roof (excluding any chimney);
>
> (c)the solar PV equipment or solar thermal equipment would be installed on a roof and within 1 metre of the external edge of that roof;
>
> (d)in the case of a building on article 2(3) land, the solar PV equipment or solar thermal equipment would be installed on a roof slope which fronts a highway;
>
> (e)the solar PV equipment or solar thermal equipment would be installed on a site designated as a scheduled monument; or
>
> (f)the solar PV equipment or solar thermal equipment would be installed on a listed building or on a building within the curtilage of a listed building."

For non-domestic properties and properties within the Conservation Area, planning permission will be required. For Listed buildings, Listed Building Consent (LBC) is required.

All roof mounted PV installations must comply with Building Regulations and North Northamptonshire Council's Building Control team will need to be notified.

For the Church specifically, the installation of a PV system on a listed place of worship is eligible for ecclesiastical exemption and, while will require permission from the relevant denominational authority, will not require Listed Building Consent. Planning permission is still likely to be required due to the Church's location within the Conservation Area.

6.1.1 Ground mounted solar PV

A ground-mounted solar PV array will require planning permission unless the array meets certain conditions for permitted development, as follows:

- Gound-mounted solar panels must be no larger than 9 square metres in area, with a maximum horizontal dimension of 3 metres in any one direction, and no higher than 4 metres.
- The ground-mounted installation must be at least 5 metres from the property boundary.

- If the property is in a Conservation Area, the solar panels must not be visible from the road.

The size of a solar farm will determine which body decides the application. In England:

- Solar farms with a generating capacity below 50 megawatts (MW) need planning permission from the local planning authority (LPA), which in this instance is North Northamptonshire Council.
- Solar farms with a generating capacity above 50 MW need development consent from the Secretary of State for Energy Security and Net Zero, because they are nationally significant infrastructure projects (NSIPs).

LPAs in England will decide applications for smaller-scale solar farms in line with their local plan and the national planning policies. Government guidance advises LPAs to approve renewable energy developments whose "impacts are (or can be made) acceptable".

Government guidance states that there "are no hard and fast rules about how suitable areas for renewable energy [developments] should be identified". It advises LPAs to consider their potential impacts on the local environment and the views of local communities when identifying suitable sites.

However, government guidance generally guides development away from the 'best and most versatile' agricultural land and states that renewable energy developments are not usually "appropriate" development for green belt land.

Generally, the process would begin with a 'screening' exercise, whereby screening is the initial stage where the proposed project is evaluated to determine whether it requires a full Environmental Impact Assessment (EIA). The aim of screening is to identify projects that have potentially significant impacts on the environment and require further assessment. If a full EIA is required, the process moves to 'scoping', where the scope of the assessment is defined. This involves identifying the potential environmental impacts and issues that need to be addressed in the EIA.

The production of an EIA can be a length process, particularly in relation to ornithology (bird) and ecology assessments are required, where monitoring of a site may be required over a period of 12 months.

If an EIA is not required, the planning application will still require to be supported by an Environmental Statement, which is less detailed than an EIA but provides evidence to confirm how environmental impacts will be mitigated against. A Habitat Management Plan will be required in both instances, to demonstrate how the site will achieve a biodiversity net gain.

Co-located solar PV and battery projects could apply for planning permission under one application.

6.1.2 Wind turbines

All onshore wind turbines, except for small-scale domestic turbines, require planning permission from the local planning authority (LPA) in England. In September 2023, the government updated national planning policy[9] to provide that LPAs should approve planning applications for an onshore wind farm if:

- It is an area identified as suitable in the local development plan (local plan or a neighbourhood plan) or a supplementary planning document.
- The planning impacts identified by the affected local community have been appropriately addressed and the proposal has community support.

The screening, scoping and planning application process would work as per the solar PV process set out above, although Locogen notes from previous experience that a full EIA would typically be expected for any wind turbine development due to the increased environmental impact, particularly around ornithology and abnormal loads

[9] Planning Update, Statement made on 5 September 2023 [https://questions-statements.parliament.uk/written-statements/detail/2023-09-05/hcws1005].

(transporting turbine components to site). Owing to the larger impacts caused by wind, planning approval is typically a much longer process.

Under the new Labour government, guidance around planning consent for onshore wind is changing to encourage the uptake of wind energy developments, although it is noted that much of this change relates to projects classified as National Significant Infrastructure Projects, with a capacity exceeding 50MW (anticipated to be increased to 100MW in the near future). As such, this is not applicable to the scale of project proposed within Nassington.

Co-located wind and battery projects could apply for planning permission under one application.

6.1.3 District heat networks

District heating networks require a significant amount of work outside home owners' curtilage, and erection of an energy centre for the centralised system (where applicable), so would require full planning permission, for both systems.

The extent of environmental information required to be submitted for a scheme of this nature is unknown. Some city-based LPAs have developed special orders which pre-emptively grants planning permission for a district heat network to be constructed where the network sits within a defined area[10]. While this does not currently apply to Nassington, the planning landscape in relation to district heat networks is changing regularly.

For comparison purposes, the Swaffham Prior scheme did submit a screening request, and were not required to produce an EIA or Environmental Statement as part of their application. They did, however, submit environmental information relating to bat surveys and a preliminary ecological appraisal. The Swaffham Prior installation was approved four months after submission, although we note that significant pre-application consultation was undertaken with a number of bodies prior to formal submission.

Where batteries are used as part of/to support the heat network, these would be applied for as part of the overarching application.

6.1.4 Domestic heat pumps

The general advice relating to domestic heat pumps is that any heat pump equipment should be sited, so far as is practicable, to minimise its effect on the external appearance of the building and its effect on the amenity of the area. In addition to this advice, regulatory procedures are detailed below for stand-alone heat pump options.

In some cases, heat pumps may be considered permitted development. Permitted development rights as per Schedule 2, Part 14 of the Town and Country Planning (General Permitted Development) (England) Order 2015 allow for changes to domestic properties without requirement for a planning application; if the installation is wholly within the building's curtilage.

ASHPs on domestic premises are generally considered to be permitted development. However, there are criteria to be met, and certain exceptions. Exceptions to permitted development rights for ASHP installations are listed below:

- Development is permitted only if the ASHP installation complies with the Microgeneration Certification Scheme Planning Standards (MCS 020) or equivalent standards.
- The volume of the ASHP's outdoor compressor unit (including housing) must not exceed 0.6 cubic metres.

[10] From Leeds City Council: The Local Development Order ('LDO') grants planning permission for the development of a District Heating Network (DHN) comprising of pipes, cables and wires, heat exchange equipment, street furniture, informational signage and ancillary engineering works within defined areas of land in the City of Leeds. [Local Development Order 3. Available at: https://www.leeds.gov.uk/planning/planning-policy/supplementary-planning-documents-and-guidance/local-development-order/local-development-order-(ldo-3)-leeds-district-heating-network].

- Only the first installation of an ASHP would be permitted development, and only if there is no existing wind turbine or ASHP on a building or within the curtilage of that property. Additional wind turbines or ASHPs at the same property requires an application for planning permission.
- All parts of the ASHP must be at least one metre from the property boundary.
- Installations on pitched roofs are not permitted development. If installed on a flat roof all parts of the ASHP must be at least one metre from the external edge of that roof.
- Permitted development rights do not apply for installations within the curtilage of a Listed Building or within a site designated as a Scheduled Monument.
- On land within a Conservation Area or World Heritage Site the air source heat pump must not be installed on a wall or roof which fronts a highway or be nearer to any highway which bounds the property than any part of the building.
- On land that is not within a Conservation Area or World Heritage Site, the air source heat pump must not be installed on a wall if that wall fronts a highway and any part of that wall is above the level of the ground storey.

For properties within Nassington that fall under the Conservation Area, domestic ASHPs that are installed on elevations facing a main road will have to obtain planning permission prior to installation.

For ground source heat pumps, in order to fall under Permitted Development, the total area of excavation for the below ground collector system must not exceed 0.5 hectares.

6.1.5 Electric vehicle charging

Typically, planning permission is not required to have an electric vehicle (EV) charger installed at a property and constitutes Permitted Development where the electrical outlet and casing does not:

- Exceed 0.2 cubic metres
- Face onto and be within two metres of a highway
- Be within a site designated as a scheduled monument
- Be within the curtilage of a listed building

Alternatively, if a ground-mounted charger (where the unit sits on a base or post) is preferred, off-street parking and ownership of the land is required. In addition, the electrical outlet and casing must not:

- Exceed 2.3 cubic metres
- Be within two metres of a highway
- Be within a site designated as a scheduled monument
- Be mounted higher than 1.6 metres from level surface used for parking vehicles
- Be within the curtilage of a listed building
- Have more than one charging point per allocated parking space

Where properties are Listed or are located within a conservation area, planning permission must be obtained for any electric car chargers.

Permitted development rights also do not extend to on-street parking, and in these circumstances planning permission is required. Please also note for on-street parking, cables must not trail across the pavement. Where trailing cables cause issues or injury, the householder may be held liable. Trailing a cable across the pavement without permission is an offence as it breaches the Highways Act 1980 Section 162 and Section 178.

Any larger scale electrical vehicle charging areas, or car parks, would require planning permission.

6.1.6 Planning application fees

There are various fees for submitting planning applications and advise requests to any local authority. Relevant fees for this project are provided in **Table 19** below.

Table 19: Planning application fees

Application	Local Authority	Fee	
Written response pre-application advice (major development)	North Northamptonshire	Unknown* Awaiting response from council Details available here: https://www.northnorthants.gov.uk/planning-and-building-control/planning-fees-and-charges	
Planning permission – install, alterations, replacement of plant and machinery	North Northamptonshire	Less than 1 hectare	£578 for each 0.1ha (or part thereof)
		Between 1 hectare and 5 hectares	£624 for each 0.1ha (or part thereof)
		More than 5 hectares	£30,860 + £186 for each additional 0.1ha (or part thereof). Maximum fee of £405,000

The recently introduced Planning and Infrastructure Bill (2025) aims to empower local planning authorities (LPAs) by allowing them to set their own planning application fees within specified boundaries. This change addresses the estimated annual funding shortfall of £362 million in LPA development management services for 2023-24, attributed to the current nationally set fees not fully covering operational costs.

Under the new provisions, LPAs can adjust fees to better reflect local circumstances and resource requirements, ensuring that planning services are adequately funded. To prevent excessive or unjustified fee increases, the Secretary of State retains the authority to intervene and direct an LPA to amend their fees if deemed inappropriate. Additionally, the legislation mandates that fee income must be reinvested into the LPA's planning functions, prohibiting cross-subsidisation of other services.

6.2 Grid

Consultation with the DNO covering Nassington (National Grid) has been sought. This section will be updated following the surgery call.

7. COMMUNITY ENGAGEMENT

To be completed alongside Kate/NEAT, and updated following in-person events in Nassington.

8. COMMUNITY BENEFITS

The proposed renewable energy systems have the potential to benefit multiple parties within Nassington and the surrounding communities. First of all, installing low carbon heating will lead to a reduction in carbon footprint and combat climate change. This will be further enhanced if renewable generation is also incorporated allowing a reduction in electricity bills. There may be further benefit from income associated with exporting surplus electricity under a SEG contract. Although it is difficult to predict the electricity prices in the current political and economic climate, it is anticipated that installing heat pumps or a heat network will also lead to reduced heating bills as the government pushes to electrify heat and incentivise tariffs in order to achieve net zero.

These benefits will lead to lower operating costs, and free up capital for other activities or incentives that can be passed back directly to the community. Renewable generation provides additional opportunities for NEAT to provide the community with a cheaper electric tariff as opposed to exporting to the grid – this not only allows community members to have savings but also generates revenue which could go back into the community activities or facilities within the village, such as hosting community events or focusing on other repairs or changes to be made.

In addition to contributing to local and national decarbonisation targets by decreasing the carbon intensity of the national grid, the projects will serve as exemplar renewable energy installations in their communities and will allow local residents and small businesses to see how to procure and operate heat pumps, heat networks, solar PV and/or wind. In terms of impacts on the wider community, installation of the proposed renewable energy systems could represent an employment opportunity for local contractors if they were to be approached by NEAT to design and install the systems. Depending on the manufacturer and model of the heat pumps chosen, annual maintenance could also be performed by a local contractor.

Locogen have explored whether the use of a groundwater source/open loop heat pump (which operates in much the same way, with the same efficiencies as a ground-source heat pump, but abstracts ground water from a borehole and reinjects it through another borehole) would be disruptive enough to the water table that it could act as a passive flood defence for Nassington. While theoretically, the abstraction of groundwater through a borehole could lower the water, this would be very localised and, for this project, unlikely to be at the scale required to make any meaningful difference to flooding issues in the east of Nassington. Equally, Environment Agency rules mean that water that is abstracted must be reinjected, to avoid unintended ecosystem or hydrological damage and as such, does not represent a practically feasible passive flood defence.

Further thoughts to be explored: Locogen project at Ledwych meant that the fields would no longer be ploughed top to bottom, which channelled rainwater off the field, and instead there would be cross field drainage installed and a retained grass coverage, both of which would hold a lot more rainwater – is this applicable here? Many more options for Natural Preservation - every GMPV project at Locogen where they have looked at Biodiversity Net Gain show a 70-100% improvement straight off the bat.

9. FINANCIAL PROJECTIONS

9.1 Project Costs

Arguably the most important and challenging aspect of the proposed renewable energy solutions is how they are financed, which is directly related to how they are owned. Further detailed are provided in Appendix A with relation to ownership and governance structures, but it is recommended that consideration is given to exploring partnership with a renewable energy co-operative. Co-ops tend to be funded by grants and also by individuals and organisations who buy shares in the co-op for a small, long-term return on their investment. Relevant examples include the Big Solar Coop and Energy4All which operate across the UK. If and when they have the resources to do so, a co-op would develop, install and own the system and manage its maintenance and export contract. Each building would benefit from reduced electricity bills from solar and heat generation used directly, but would not receive any income from exported solar electricity unless it invested in the co-op. It is important to note that while there are co-ops that do both renewable electricity and heat installations, a larger number of co-operatives focus on solar PV installations only. The advantage of this option is that it allows a hands-off approach from the group, as well as significantly reduced, or indeed zero capital costs. Conversely, the co-op may have limited capacity for new systems which may result in a long-waiting list or competitive application process.

The project costs associated with the heat pump, solar PV and wind systems outlined below have been estimated based on prior experience, and where possible, have been verified by from suppliers. Costs have also been applied, where appropriate, from CEF Guidelines on project costs.

9.1.1 Development Costs

Typically, the key components of development costs would be planning fees to the local authority, grid connection costs and surveys / consultations. Stand-alone ASHPs would not have any associated planning or grid costs involved. It has been assumed that although some properties are located within the conservation area, the ASHPs would be positioned to the rear of the properties not facing the main road thus negating the need for planning permission. This would be required to be reviewed on a case-by-case basis. Likewise for grid connection, due to the low supply demand required for an ASHP, the likelihood of requiring a supply upgrade at each property is very low; however this option has been excluded in this section as it would not fall under NEAT's remit but on the individual householder.

For the ambient loop scenario, an estimate of £3,000 for electrical upgrades have been taken into account for properties with a higher heat loss that typically would not fit a single phase GSHP or a single unit ASHP. For this project, it is anticipated that approximately 23% of properties will require these upgrades.

A project of this size will undergo numerous surveys such as, but not limited to, ecology, landscape visual impact assessment, glint and glare (for solar PV) and shadow flicker assessments (for wind). Furthermore, community and planning consultations will form an important part of the process in addition to project management. All surveys and management costs include a 10% contingency amount.

Table 20: Estimated development costs for heat network and generation solutions

System	Item	Cost
High temperature heat pump	Planning	£12,480
	Grid connection (estimated)	£1.0m
	Surveys and management	£30,000
Ambient loop heat pump	Planning	£6,240

	Grid connection (estimated)	£255,000
	Surveys and management	£30,000
2MW solar array	Planning	£25,000
	Grid connection (estimated)	£1.0m
	Surveys and management	£60,000
1MW wind turbine generator	Planning	£12,480
	Grid connection (estimated)	£1.0m
	Surveys and management	£190,000

9.1.2 Capital Costs

The capital expenditure (capex) for all elements of the project were obtained through means of discussions with, and quotations from third parties, Locogen's consultancy and installation experience and CEF guidance. As projects progress, there is always the risk that unforeseen costs occur. In order to account for this possibility, a 10% contingency has been included within the total capex for the project.

Table 21 below summarises the capex for the different aspects that is under consideration in this study.

Table 21: Estimated capital costs for heat network and generation solutions

	High temperature system	Ambient loop system	2 MW solar array	1 MW wind turbine	Private wire
DHN capex	£2.15m	£1.86m	£0	£0	£0
Plant capex	£2.50m	£4.46m	£1.13m	£1.8m	£432k
DEVEX	£1.04m	£291.2k	£85k	£202.5k	£0[11]
Total	**£5.69m**	**£6.61m**	**£1.22m**	**£2.0m**	**£432k**

The costing for the high temperature (3rd or 4th generation, centralised) system consists of the total materials and labour required to install district network to each building from a central energy centre where a single GSHP system and associated equipment would be located. The development cost associated with this option is primarily project management, consultation with planning and community, surveys, permits fees and the grid upgrade costs.

The ambient loop total cost also takes into account the same district network (as it will follow the same route), but unlike the singular heat pump system, this approach would see individual domestic heat pumps being purchased for each building. Due to each heat pump catering to the individual properties heat demand alone, it negates the need for a substantial grid upgrade cost which ultimately allows this option to more competitively valued. It should be noted that some properties will still require electrical upgrades, which have been accounted for in the costing. It is

[11] Development costs included within district heating network costs.

also understood that radiator upgrades may be applicable to a number of properties due to the low flow temperature from by the system.

The cost of the 2 MW solar array takes account of the plant (solar panels, inverter, wiring/ cable materials and civil works). The development costs involved with a solar farm includes: project management, screening, planning (including fees, design, drawings and liaison), landscape and visual impact assessment, ecology surveys, glint and glare assessment, agricultural land classification survey and transmission impact. Grid costs have been included as part of the high temperature system because the generation will be connected to the meter that will be supplying the large GSHP. For ambient loop, an additional £1.0m has been added to account for the generator to be connected onto the national grid, but it will also feed directly into individual properties via private wire.

The wind turbine outlay considers the plant (turbine foundations, turbine supply and install), the civil and electrical contracts and cabling. The associated development costs with erecting a turbine are high, the value stated above includes project management, screening, aviation works, landscape and visual assessments, noise/ impact monitoring and report, ecology works, shadow flicker assessments, transport assessment and the supply, install and decommissioning of a meteorological mast.

The private wire total includes only the materials (cable) and cost of connection point per property.

The total costs for the different heat network and generation configurations that were used for financial modelling are noted in table below.

Table 22: Capital costs used for each heat network scenario within financial modelling

Scenario	High temperature system	Ambient loop system
Heat pump only	£5.65m	£6.67m
Heat pump and solar PV	£6.87m	£8.24m (with private wire)
Heat pump and wind	£7.65m	£8.91m (with private wire)

9.1.3 Operation and maintenance costs

The main operational costs associated with heat network systems are the electricity costs for running the heat pump. Aside from this, the only other fee is the cost associated with the routine annual maintenance of the system to ensure it is running at optimal conditions. The estimated yearly fees for the various systems are noted in the table below. It should be noted that because the ambient loop option would involve the Client owning the heat pump and renting to the home owners, the fee is slightly higher as it is comprised of annual maintenance fee and annual charge for heat pump equipment. To generate a revenue for the owner, a 10% margin has been adopted for high temperature and ambient loop systems.

Table 23: Maintenance costs for different heat network/standalone solutions

System	Annual Cost
High temperature system (network operator)	£9,350
Ambient loop system (per property owner)	£635
Stand-alone system (per property owner)	£200

9.2 Financial and carbon projections

The tables below demonstrate the anticipated financial returns of the different heat solutions for both network operator and end user. If the project was grant funded, only the net annual benefit would be relevant. It should be noted that the net benefit to NEAT takes into account the maintenance and cost to run each system against the income generated. Estimate grid upgrades costs have been included as part of the capital cost – *these will be updated once feedback has been received from National Grid with regards to budget cost estimates*. The financial returns were modelled over a 50 year period to determine which is the most suitable option for both NEAT and the community members/householders.

For all cases, the net benefit stated is the direct comparison against the 'business as usual' (BaU) case (existing oil boilers). For all cases, it is assumed that **all** residents in Nassington sign up to the heat network at Year 1.

9.3 Financial and carbon projections without renewable generation

9.3.1 High temperature heat pump system

Network owner/operator

The figures detailed below within Table 24 are the costs incurred/benefited by the network operator or owner.

Table 24: Anticipated high temperature system project returns – network operator

Item	
Capital cost	£7.84m
Operation & Maintenance	£9,350
Electricity price	28 p/kWh
Sale price of heat (Y1)	**11 p/kWh**
NPV Y20	-£8.95 m
IRR Y20	No return
NPV Y40	-£10.8 m
IRR Y40	No return
Payback years	No payback
Carbon offset Y20	263 tonnes
Carbon offset Y40	126 tonnes

Householder

The figures detailed below within Table 25 are the costs incurred/benefited by the householder/end user.

Table 25: Anticipated high temperature system project returns – householder

Item	
Capital cost	£2,000
Annual costs	£25

Heat demand	12,372 kWh
Cost of Heat (Y1)	**11 p/kWh**
NPV Y20	£2,385
IRR Y20	9 %
NPV Y40	£6,771
IRR Y40	11 %
Payback years	9 years
Carbon offset Y20	0.7 tonnes
Carbon offset Y40	0.3 tonnes

Summary

The financial analysis undertaken for a high temperature system demonstrates that while this option represents a meaningful investment to the householders of Nassington, with a payback period below 10 years, the system does not provide a financially feasible investment for NEAT as the owner/operators, with the project costing more to operate than it earns each year.

9.3.2 Ambient loop heat pump system

Network operator

The figures detailed below within Table 26 are the costs incurred/benefited by the network operator or owner.

Table 26: Anticipated ambient loop system project returns – network operator

Item	
Capital cost	£6.67 m
Operation & Maintenance	£54,797
Electricity price	28 p/kWh
Sale price of ambient heat	**5 p/kWh**
NPV Y20	-£3,25m
IRR Y20	-6.2 %
NPV Y40	-£265k
IRR Y40	0%
Payback years	40 years
Carbon offset Y20	174 tonnes
Carbon offset Y40	83 tonnes

Householder

The figures detailed below within Table 27 are the costs incurred/benefited by the householder/end user.

Table 27: Anticipated ambient loop system project returns – householder

Item	
Capital cost	£2,200
Annual costs	£635
Heat demand	12,372 kWh
Electric demand	3,749 kWh
Cost of ambient heat	**5 p/kWh**
NPV Y20	-£15,308
IRR Y20	No return
NPV Y40	-£29,963
IRR Y40	No return
Payback years	No payback
Carbon offset Y20	0.5 tonnes

Carbon offset Y40	0.2 tonnes

Summary

In direct contrast to the high temperature heat network, the financial analysis for an ambient loop system shows that NEAT as the owner/operators would have a system which 'pays back' within 40 years, but represents a poor investment for the householders of Nassington, who would be paying substantially more per year than their current heating systems. This then represents a risk of low numbers of residents signing up to the network, as it offers them no tangible benefits.

9.3.3 Stand-alone heat pump system

The figures detailed below within Table 28are the costs incurred/benefited by the householder/end user whereby a heat network is not considered, and instead, all houses in Nassington are fitted with an individual heat pump.

Table 28: Anticipated stand-alone system project returns – householder

Item	
Capital cost	£10,751
Annual costs	£200
Heat demand	12,372 kWh
Electric demand	4,266 kWh
Cost of fuel (Y1)	**28 p/kWh**
NPV Y20	-£6,532
IRR Y20	-8%
NPV Y40	-£2,312
IRR Y40	-1%
Payback years	No payback
Carbon offset Y20	0.54 tonnes
Carbon offset Y40	0.26 tonnes

Sensitivity analysis in relation to the electricity tariff used has confirmed that the unit cost of electricity would need to reduce to 20p/kWh in order for a stand-alone air source heat pump within the average Nassington home to 'pay back' within 20 years (i.e. the expected lifespan of a domestic air source heat pump).

It should be noted that if the route of stand-alone ASHPs was taken, individual home owners would be able to access a £7,500 grant as part of the Boiler Upgrade Scheme, as long as the system is installed by an MCS approved installer.

9.4 Financial and carbon projections with solar PV addition

9.4.1 High temperature district heat system

Network operator

The figures detailed below within Table 29 are the costs incurred/benefited by the network operator or owner.

Table 29: Anticipated high temperature system project returns with solar generation – network operator

Item	
Capital cost	£8.35m
Operation & Maintenance	£69,350
Electricity price	28 p/kWh
Sale price of fuel	**11 p/kWh**
NPV Y20	-£255k
IRR Y20	-0.29%
NPV Y40	£7.84m
IRR Y40	3.72%
Payback years	20 years
Carbon offset Y20	54 tonnes
Carbon offset Y40	26 tonnes

Householder

The figures detailed below within Table 30 are the costs incurred/benefited by the householder/end user.

Table 30: Anticipated high temperature loop project returns with solar generation – householder

Item	
Capital cost	£2,200
Annual costs	£1,996
Heat demand	12,372 kWh
Electric demand	3,749 kWh
Cost of fuel	**11 p/kWh**
NPV Y20	-£10k
IRR Y20	No return
NPV Y40	-£17.8k
IRR Y40	No return
Payback years	No payback

Carbon offset Y20	0.47 tonnes
Carbon offset Y40	0.23 tonnes

Summary

In much the same way as the ambient loop heat network, the financial analysis for a high temperature loop system coupled with a private wire connection to a solar PV plant shows that NEAT as the owner/operators would have a system which 'pays back' within 20 years, but represents a very poor investment for the householders of Nassington, who would be paying substantially more per year than their current heating systems. This then represents a risk of low numbers of residents signing up to the network, as it offers them no tangible benefits. The numbers presented in Table 29 rely on all Nassington householders signing up to the network in Year 1. If this is unfulfilled, a high temperature heat network with solar PV generation is no longer financially viable.

9.4.2 Ambient loop system

Network operator

The figures detailed below within Table 31 are the costs incurred/benefited by the network operator or owner.

Table 31: Anticipated ambient loop project returns with solar generation – network operator

Item	
Capital cost	£8.24 m
Operation & Maintenance	£66,974
Electricity price	28 p/kWh
Sale price of heat (Y1)	**3.2 p/kWh**
NPV Y20	-£6.14 m
IRR Y20	-11 %
NPV Y40	-£4.04m
IRR Y40	-3 %
Payback years	50 years
Carbon offset Y20	54 tonnes
Carbon offset Y40	26 tonnes

Householder

The figures detailed below within Table 32 are the costs incurred/benefited by the householder/end user.

Table 32: Anticipated ambient loop project returns with solar generation – householder

Item	
Capital cost	£2,200
Annual costs	£1,031
Heat demand	12,372 kWh
Electric demand	3,749 kWh
Cost of fuel	**3.2 p/kWh**
NPV Y20	£9,292
IRR Y20	26 %
NPV Y40	£20,785
IRR Y40	26%
Payback years	3 years
Carbon offset Y20	0.47 tonnes

Carbon offset Y40	0.23 tonnes

Summary

The financial analysis undertaken for an ambient loop system coupled with a private wire connection to a solar PV plant demonstrates that while this option represents a meaningful investment to the householders of Nassington, with a payback period of 3 years, the system does not provide a financially feasible investment for NEAT as the owner/operators, with the project not breaking even until after 50 years of operation. At this point, major items of plant and potentially some elements of the network would be required to be replaced, effectively meaning that the cycle of 'pay back' begins again. This prevents the creation of any community benefit funds (or similar), established from any owner/operator profits.

9.5 Financial and carbon projections with wind addition

9.5.1 High temperature system

Network operator

The figures detailed below within Table 33 are the costs incurred/benefited by the network operator or owner.

Table 33: Anticipated high temperature system project returns with wind generation – network operator

Item	
Capital cost	£7.65m
Operation & Maintenance	£69,350
Electricity price	28 p/kWh
Sale price of fuel	**11 p/kWh**
NPV Y20	£2.72m
IRR Y20	3.1%
NPV Y40	£13.1m
IRR Y40	6.15%
Payback years	14 years
Carbon offset Y20	91.9 tonnes
Carbon offset Y40	44.1 tonnes

Householder

The figures detailed below within Table 34 are the costs incurred/benefited by the householder/end user.

Table 34: Anticipated high temperature system project returns with wind generation – householder

Item	
Capital cost	£2,200
Annual costs	£1,996
Heat demand	12,372 kWh
Electric demand	3,749 kWh
Cost of fuel	**11 p/kWh**
NPV Y20	-£10k
IRR Y20	No return
NPV Y40	-£17.8k
IRR Y40	No return
Payback years	No payback

Carbon offset Y20	0.47 tonnes
Carbon offset Y40	0.23 tonnes

Summary

In the same way as the ambient loop heat network and the high temperature heat network with solar PV private wire, the financial analysis for a high temperature loop system coupled with a private wire connection to a wind turbine shows that NEAT as the owner/operators would have a system which ‘pays back’ within 14 years, but represents a very poor investment for the householders of Nassington, who would be paying substantially more per year than their current heating systems. This then represents a risk of low numbers of residents signing up to the network, as it offers them no tangible benefits. The numbers presented in Table 33 rely on all Nassington householders signing up to the network in Year 1. If this is unfulfilled, a high temperature heat network with wind generation is no longer financially viable.

9.5.2 Ambient loop system

Network operator

The figures detailed below within Table 35 are the costs incurred/benefited by the network operator or owner.

Table 35: Anticipated ambient loop project returns with wind generation – network operator

Item	
Capital cost	£8.91 m
Operation & Maintenance	£66,974
Electricity price	28 p/kWh
Sale price of fuel	**3.2 p/kWh**
NPV Y20	-£4.53m
IRR Y20	-6 %
NPV Y40	-£162k
IRR Y40	-0.1%
Payback years	40 years
Carbon offset Y20	92 tonnes
Carbon offset Y40	44 tonnes

Householder

The figures detailed below within Table 36 are the costs incurred/benefited by the householder/end user.

Table 36: Anticipated ambient loop project returns with wind generation – householder

Item	
Capital cost	£2,200
Annual costs	£1,031
Heat demand	12,372 kWh
Electric demand	3,749 kWh
Cost of fuel	**3.2 p/kWh**
NPV Y20	£9,292
IRR Y20	26 %
NPV Y40	£20,785
IRR Y40	26%
Payback years	3 years
Carbon offset Y20	0.47 tonnes

Carbon offset Y40	0.23 tonnes

Summary

This option represents the most financially viable solution, with payback of the system seen for both the owner/operators and the householders within the lifetime of the network and main plant items. Substantial risk remains in relation to the co-ordination of a wind turbine with neighbouring MOD and airfield infrastructure, and updates from these consultees will be updated in this report once received.

9.6 Financial projections summary

Financial analysis has been undertaken on various different opportunities relating to a holistic low-carbon solution within Nassington, exploring the impacts of different combinations of heat network and renewable energy generation. All of these solutions have been benchmarked against the counterfactual – i.e., properties in Nassington continue to use a mix of electric heat pumps, direct electric heating and oil fired boilers, using an electricity tariff of 28p/kWh and an oil cost of 11p/kWh.

An option of all properties within Nassington switching to air source heat pumps has also been explored.

In summary, the only options which benefits both the residents of Nassington, and NEAT as owner/operators of a proposed heat network and renewable energy generating installation is the option comprising an ambient loop heat network, selling heat to residents at 3p/kWh, coupled with a private wire connection to all houses from a 1MW wind turbine. This option sees the installation 'paid back' to NEAT in 40 years, and paid back to the householders in 3 years.

It is hugely important to note that this modelling and the success of this solution assumes that **all houses** in Nassington wish to join the network and do so in Year 1 of the heat and private wire network being constructed. Where this is not the case, the financial projections rapidly deteriorate with regards to payback periods, as the DEVEX and CAPEX costs of the network are only marginally reduced by less houses connecting, with the majority of costs related to the heat/electricity generating plant and installation of the network pipework/cabling.

10. OPERATION AND GOVERNANCE

In addition to the high level overview of how such a project could be operated and governed, as set out below, Appendix A sets out different ownership and governance structures that could be applicable to a project of this type.

10.1 Operation

Once commissioned, the heat network will be able to operate without interference. The main burden is associated with the administration of private wire to ensure that the project generates income from its surplus generation. This is a very similar process to managing electricity import contracts, therefore no specialist experience or training will be required.

The main operational activities and associated hours for a heat pump of the project size involves the following:

- Visual inspection, checking for leaks and unusual noise at both the network and heat pump;
- Cleaning of the heat pump shell and tube heat exchanger; and
- Troubleshooting of minor fault alarms.

All training of in-house staff should be provided by the heat pump suppliers to ensure that routine operation and maintenance requirements are understood by multiple staff.

For wind turbine generators, no specific requirements are required apart from annual servicing. However, administrative works related to the land the plant is on will be required which is why it is suggested that a company operates the generation asset to alleviate the burden from NEAT.

Allowances should be made for component failure and replacement parts. Typically, it is recommended that a contingency fund be put aside to cover replacement parts over time. An annual allowance of approximately 2% of the capital costs of the project would be a reasonable contingency fund.

10.2 Governance

Delivery and ongoing management of the project will be led by NEAT who will also be responsible for the final decisions regarding the size and scale of technologies to be installed, the timescales across which technologies will be installed, and securing funding and relevant permissions and permits.

Responsibility for the operation and maintenance of the DHN will fall upon the owner. In many cases this is the local council, however with this development, it is suggested that the Client appoint a reputable company to undertake the operation and maintenance of the network. Ongoing monitoring and maintenance requirements are minimal as should reactive maintenance requirements, assuming correct installation of the DHN components.

The DHN owner will have to meter and bill consumers which takes up administrative time and will also need to set up a charging structure which is assumed to include a base charge for use of system as well as a charge per unit of energy used. The following therefore must be considered in operating and maintaining a DHN:

- Annual servicing/maintenance costs (pipework and heat interface units);
- Metering and billing costs;
- Replacement costs;
- Service charges; and
- Delivered energy charges.

The heat network and associated equipment will require ongoing scheduled maintenance and an annual service to ensure efficient operation. This would be the case for fossil fuel boilers and standalone heat pumps as well. Several additional operational activities will need to be performed regularly.

11. SCHEDULING

An implementation pathway for developing the project is presented below in the figure below. They show the key decisions that should be put in place in order for the project to progress.

Site survey from potential installers/ contractors

Confirm heat demands for all properties in detail, and propose equipment sizes and firm costs

↓

Apply for grid connection

Grid connection applications will have to be made to the DNO for both heat pump and renewable generation technologies to recieve firm quotes

↓

Pre-planning

Seek advice from local authority, depending on feedback the capacity of generation may have to be curtailed and other elements of design modified

↓

Fundraising

Submit application for funding/ seek funding oppourtunities for the installation(s)

↓

Planning application

Submit planning application to local authority

↓

Tendering

Prepare tender document and issue to at least three contractors

↓

Installation & operation

Install and commission technologies, then look to secure tariff with DNO for any excess generation exported to grid

12. CONCLUSIONS

In this study, the feasibility of implementing low carbon solutions in Nassington was explored. This report has discussed and analysed a range of low carbon renewable heat options, with particular emphasis on district heat networks, which may be implemented across the village of Nassington.

The project had aimed to encourage an uptake of energy efficiency and low carbon measures in rural regions and in addition to reducing energy bills, it would ultimately support the push to reduce emissions, improve air quality, and become a trail blazer for other villages to follow suit.

Key findings demonstrate that both 4th and 5th generation heat networks could feasibly serve the village from a technical perspective and represent either a financially viable solution for NEAT as the owner/operator, OR the householders of Nassington, but that the only financially feasible solution for both NEAT and the residents would be an ambient loop heat network coupled with a 1MW wind turbine and private wire connections to all properties.

Electricity generation analysis concludes that a 1 MW wind turbine provides greater alignment with Nassington's seasonal heating load profile compared to solar PV, which overgenerates in summer and underperforms in winter. Innovative technologies such as high-temperature thermal sand batteries were modelled but not advanced due to CAPEX, land requirements, and unproven operational precedents. Hybrid integration with low-temperature thermal stores may hold future potential pending further technology maturation.

Grid constraints, planning limitations, and building diversity will ultimately influence the final system configuration, while the success of this network will depend heavily on the uptake from Nassington residents, and financial modelling has assumed that all properties would be willing to connect at Year 1. Where this does not happen, the financial returns for the owner/operator are negatively impacted.

12.1 Recommended Next Steps

It is recommended that the following next steps are undertaken as part of the CEF Stage 2 funding round.

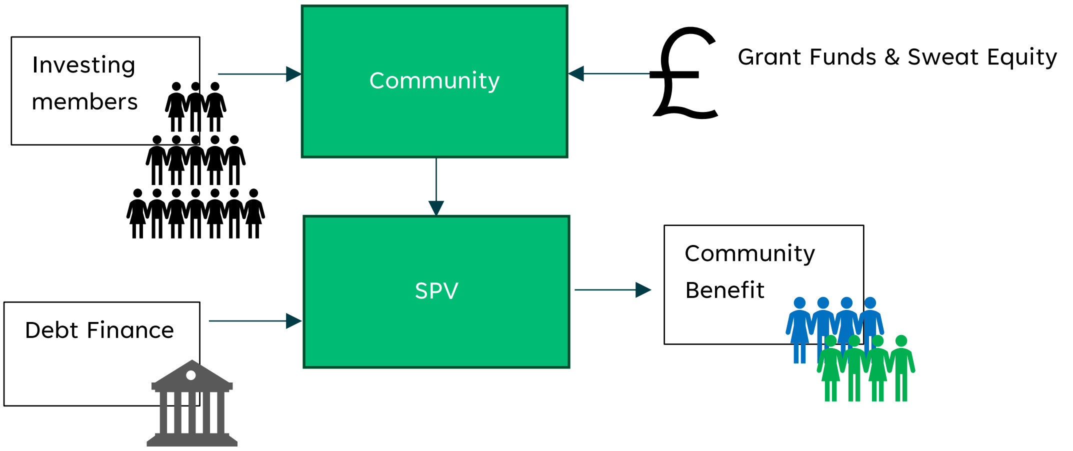
- Detailed Network Analysis
    - Geotechnical surveys for heat pump borehole viability
    - Phased heat network routing and hydraulic loss modelling
- Generation and Storage Planning
    - Engage DNO for confirmed grid connection/export capacity
    - Secure preliminary landowner agreements for wind and energy centre sites
    - Commence planning pre-application discussions
    - Technical specification for 1MW wind and (potentially) BESS integration
- Community Engagement
    - Targeted homeowner engagement for retrofit willingness
    - Workshop on heating controls and performance expectations
    - Dissemination of comparative case studies
- Financial Modelling
    - Finalise NPV, IRR, and LCOE assessments for each configuration
    - Explore funding pathways: Green Heat Network Fund, CEF, blended finance
    - Model sensitivity against energy price volatility

- Governance and Delivery
    - Define project delivery structure (e.g. CIC, Co-op, local ESCO)
    - Draft outline business case and risk register

Appendix A. Community models and legal structures

Outline of model options

The following diagram presents how a community led energy project is typically structured.



The SPV or Special Purpose Vehicle is an independent legal entity that owns the asset or assets. The legal structure of the SPV depends how the community decide to fund the project and how it will be governed.
Community or Social Enterprises take different legal forms and can be used in different ways. The structure which best suits a community depends on how the community is defined and what it is trying to achieve. The following sections explains the different structures that are currently adopted for community energy projects in the UK. The SPV structure that is adopted is often a compromise between what works legally, financially and what local conditions and/or preferences may ordain.

Co-operative Society (Co-op)

Co-operative societies are a form of registered society and are operated for the benefit of their members, rather than being operated for the benefit of the community other than its members. Co-operatives operate on the principle of "one member one vote" and were, in previous years, a popular choice for community energy schemes since generated profits which could be applied for the benefit of the members of the co-operative.
The Financial Conduct Authority has, however, in recent years made it extremely difficult to permit the registration of new energy cooperatives due to its interpretation of what a co-operative is as an organisation which must trade with its members. The FCA's current interpretation is that this requirement is not generally satisfied by the specifics of community energy projects where energy runs through the grid and the Co-operative is not selling the energy directly to its members.

Community Benefit Society ('Bencom')

A Community Benefit Society is similar to a Co-operative Society except that the Society's objectives benefit a wider community (or deliver an identified social priority) and not primarily of financial benefit to investors in the Society. It may raise capital through a community or public share offer in the same way as a co-op, with similar regulatory exemptions. The Bencom is now widely adopted in the UK for community energy, given the regulatory restriction on the co-op structure. A Bencom is the only UK Society that can raise share capital and sell electricity to the wholesale market (rather than its members), pay share interest to members and distribute surplus profit for community benefit. One distinction between a Bencom and a co-op is that all profit is for community benefit. Financial return on members' capital in a Bencom is restricted to a rate considered reasonable and sufficient to raise and retain the capital needed to run the business.

Charity

In Scotland there is a culture of charities owning renewable energy projects. Charities are often more trusted by communities, especially if they already exist and have been representing a community's interest for a number of years. A Charity however is limited in how it raises capital. It may apply for public funds, funds from private foundations or donations from members of the public.   These funds may be applied (along with debt finance) to a wholly owned SPV which donates any surplus profit back to the Charity for distribution. The main issue with applying the charity model is the limitation on projects based on the amount of money that can be raised. It is also limited in its engagement with local people by only being allowed to apply its benefit to those that meet its charitable purpose.

Public Limited Company ('PLC')

A PLC structure can be considered if the amount of money that needs to be raised for projects is large. PLCs are also open for anyone (individual or organisation) to invest, limited only by the number of shares available. Unlike a private company limited by shares, a PLC can make an offer of securities to the public. This can either be done via the publication of an approved prospectus under the Prospectus Regulations or shares in a PLC can be admitted to trade on a stock exchange or other market. Typically shares in a PLC will be freely transferable without substantial restriction.

Voting rights for shareholders in a PLC operate on the one share one vote principle; therefore, those investors with the greatest number of shares have the most influence on running the business. For this reason, a PLC, whilst a 'public' organisation and open to anyone, does not lend itself to a community energy project. However, there are a number of ways in which a PLC can be modified to convert the organisation into a social enterprise:

- Prioritise local investment when issuing a share offer. The offer can give priority to certain investors, ensuring the local community can receive its full allocation before inviting investment from the general public.
- Introduce an Asset Lock, which means the company or assets can only be sold to an organisation with similar community objectives. Also, investors can only receive up to their original stake back if the company is wound up (all surplus goes towards the objectives of the organisation).
- Prevent shareholders from transferring shares without permission of the Board.
- A PLC can also adopt Co-operative Principles and values in its Memorandum and Articles and introduce one member one vote.

However, such changes may negate the perceived benefits of a PLC.

In the UK a legal form called a Community Interest Company ('CIC') has been created. A CIC is a relatively new type of limited company for those wishing to establish businesses with a social purpose or to carry on other activities for the benefit of the community. The CIC is particularly suitable for those who wish to work with the relative freedom of the familiar limited company framework without either the private profit motive or charitable status. A CIC has to pass a community benefit test which is carried out by the regulator. This additional layer of administration should prevent the model being abused. However, CICs have proved to be unsuitable for community ownership in the UK because 65% of profits have to be distributed to community benefit, making returns to investors restrictive when raising capital.   However, in the case of Glastonbury, where grant funds can be applied, it may be possible to meet 65% community benefit (often referred to as a Special Share) and deliver an attractive return to investors if the business can be made profitable enough.

Individuals Loan to SPV

This is an investment model and not generally considered to be a 'community' enterprise. It is often referred to as crowd funding, since online platforms of this type are typically used to arrange loans or debentures with individuals and manage their investment. The monies raised through these individual loans are then lent to a project SPV. A

Bencom may use a crowd funding platform to raise debt finance to compliment its share capital when funding a project.

Key Features:

- A simple way to engage individuals with the project but they are typically not connected with each other, hence not considered a community or participating in the business in any way, therefore less engaging.
- Promotion of the offer and application process is typically online and the investors can come from anywhere.
- With no principles of co-operation individuals are investing for their own financial benefit.
- It is relatively cheap to set up and automated once in operation.
- There is little or no community purpose in raising the money (apart from the narrative).
- Exclusive only to individuals with internet access.
- Maybe cheaper than bank finance which often has high due diligence costs and arrangement fees.

Innovative Models

Linking Community Investment and Community Benefit

An option not previously implemented in the UK, but considered a viable option is that of combining community investment with community benefit i.e the local community own the SPV. The key critical point is that the benefit fund remains democratically controlled by the local community and not by the investing members. Traditionally, there is a clear split between the community benefit fund and community entity investing in the project, each governed separately. This split is sometimes deemed necessary so that the community benefit fund can be governed by a local board of trustees, where the community ownership entity has members from further afield with a say in how profits are distributed

Rather than creating and operating two entities with their own boards and separate admin costs, it is possible for the whole community to engage through a single community entity if everyone in the local community becomes a member. This would give local residents an equal say in how the profit of the business is distributed. This could be achieved for instance if all residents that live in Nassington were given one free voting share along with the opportunity to invest. If additional capital is required, the offer to invest could then be opened up to people outside the community by issuing bonds without voting rights (or crowd funding platforms). The community benefit fund (effectively the profits of the community entity) would then be democratically governed by a local, representative membership to distribute however they democratically please. This model has the benefit of potentially engaging more local people with the project than a separate community benefit and investment fund as it should appeal to everyone and everyone has an equal say.

Discount on Energy Bills

There is a model pioneered by Ripple Energy that links the electricity generated by a members' share in a project with a discount on their energy bill. An investor may purchase a share of a generation project, capped in kWh that matches their annual household electricity demand. The amount produced by their share of the generator (at wholesale price) will be taken off their bill each quarter. The FCA has deemed this sufficient member participation for the entity to trade as a Co-operative Society. This model is particularly attractive for those who can afford to invest, but it doesn't create a community benefit unless the members collectively decide to make one.

Non-Standard PPA Contracts

Typically, a grid connected generator will sell electricity to the Energy Supply market through a PPA (Power Purchase Agreement) contract. The price received for electricity is a wholesale price that varies according to the market price offered when the contract is arranged. The contract can be for 6 months or a year (sometimes longer) and the generator has to estimate what the future price of the contract will be throughout the life of the project when planning the business.

With changes to regulation, advances in metering and online billing platforms it has recently become possible for Energy Suppliers to sell electricity from a specific generator to a business customer through a Sleeving or Corporate PPA contract. There could conceivably be opportunities for those who invest to get reductions in their electricity bill or apply community benefit to support local people in fuel poverty with a lower electricity tariff. Energy Local can be applied to projects that connect to the grid at the same voltage as a local off-taker. The benefit of this model is that some of the network system charges are not applied to the generator. With the use of smart meters for domestic users, it's possible to set up an Energy Local club so that local people connected to the same primary substation as the generator can buy the electricity at a price agreed between the generator and the club

These are the PPA options to consider in order of value. The PPA would be advantageous to both parties:

- **Private wire**: Ideally this would be to a local off-taker (such as Mee's Farm) where the generator off-sets the off-taker's electricity at retail price for a lower price agreed between the parties.
- **Synthetic PPA:** a financial agreement like a Contract for Difference (CfD) with the Local Authority or local business. A strike price is agreed and the difference between the market price and the strike price is paid to either party, depending on whether the market price is lower or higher than the strike price.
- **Sleeved PPA**: preferably with a long-term trading high energy demand user on the same primary substation as the generating project (connected at the same voltage) to benefit from the Ofgem derogation that Energy Local uses.
- **Corporate PPA**: a long-term PPA with an established business that could in theory be anywhere on the network but doesn't necessarily benefit from the OFGEM derogation that reduces network charges. One benefit is a long-term known PPA price with a reputable company, which could be considered more secure for some investors. If there is a big local employer that uses a lot of energy this option could help engage more local people with the project.
- **Market PPA**: the "base case".

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