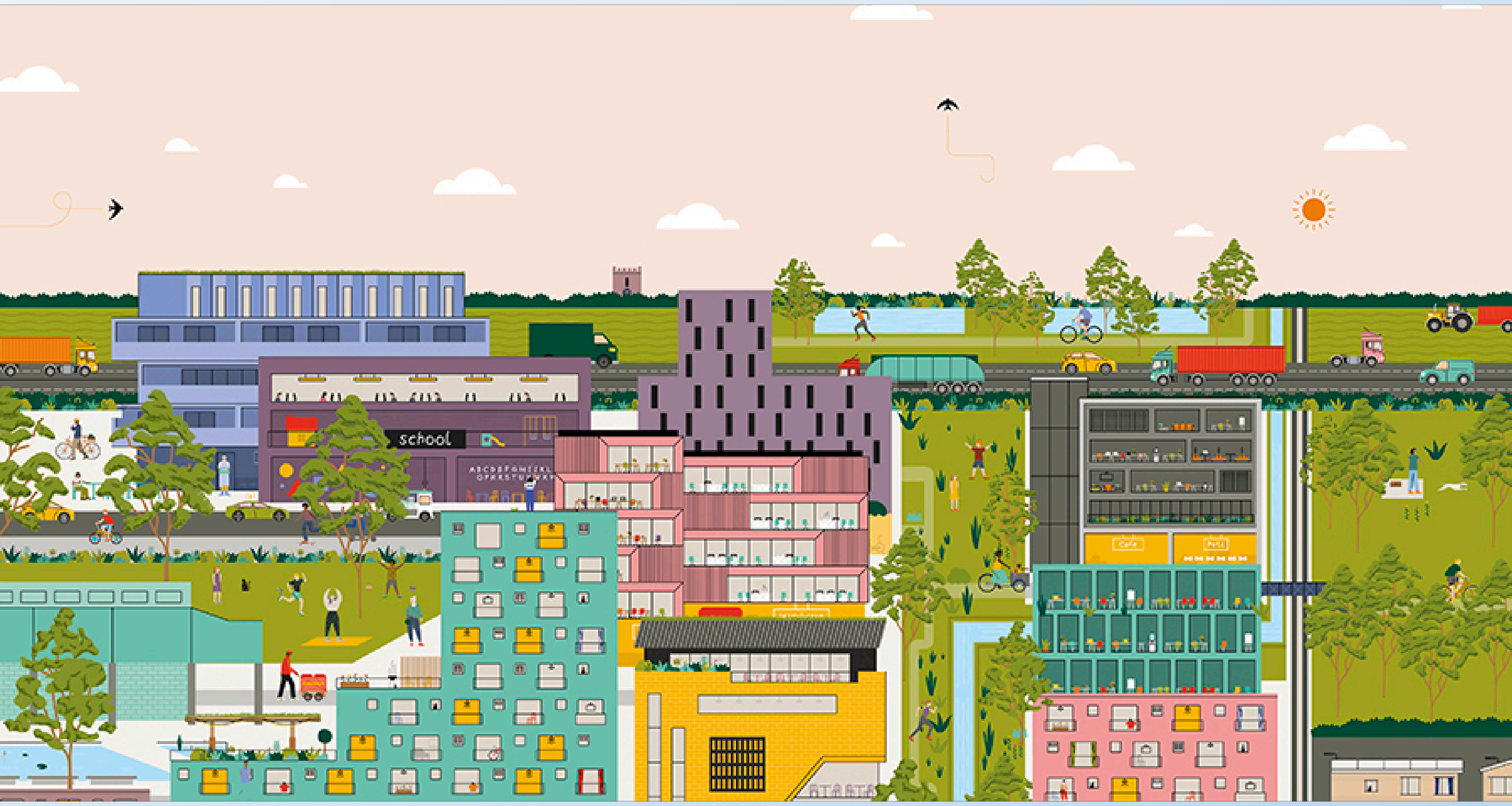
Greater Cambridge Shared Planning

NORTH EAST CAMBRIDGE SITE WIDE ENERGY AND INFRASTRUCTURE STUDY AND ENERGY MASTERPLAN



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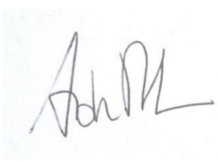
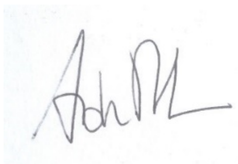
Signature			
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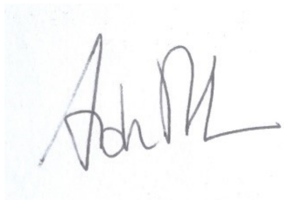
Signature			
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ACRONYMS

Biomass - Refers to any fuel derived from organic matter generally wood, but also includes straw, grass and organic waste.

BREEAM - Building Research Establishment Environmental Assessment Method, a sustainability accreditation primarily for buildings

Capacity - The capacity of the system is the maximum power output. It depends on the installations size and technical capability. The capacity may be in terms of electrical or thermal output.

Combined heat and power (CHP) - A system which generates electricity whilst also capturing usable heat generated in the process. Typically, when referring to CHP it is inferred that this is gas-fired though this does not necessarily need to be the case.

District Heating – a form of heating involving the generating of heat suitable for heating and domestic hot water centrally before distributing via buried pre-insulated pipework to users.

DSR – Demand Sider Response is a mechanism where energy loads are increased or decreased by the end user to assist maintaining integrity of the electricity grid.

GEC – Ground Energy Collector, typically used in conjunction with a heat pump systems

GHG Emissions – Greenhouse gas emissions, typically expressing in terms of carbon dioxide equivalents

GWP – Is the Global Warming Potential of a refrigerant often expressed in carbon dioxide equivalents. The timescale the value refers to may be in the order of 50 or 100 years

Heat Pump - A heat pump is a device that transfers thermal energy from a heat source to a heat sink (e.g. the ground to a house). There are many varieties of heat pump e.g. air, ground and water source heat pumps. The first word in the title refers to the heat source from which the pump draws heat. The pumps run on electricity, however less energy is required for their operation than they generate in heat, hence their status as a renewable technology.

kW - KW stands for kilowatt. A watt is a unit of power and a kilowatt is a thousand watts.

kWh - kWh stands for a kilowatt hour and is a unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at a kilowatt power output.

MVA – MVA stands for megavolt ampere, a unit used for the apparent power

MW - MW stands for megawatt. A watt is a unit of power and a megawatt is a million watts.

MWh - MWh stands for a megawatt hour and is a unit of energy. It is equal to the amount of energy a system will generate in an hour whilst running at a megawatt power output.

Power Purchase Agreements (PPA) – Contractual agreements for the purchasing of electrical power.

Photovoltaics – Rooftop or ground-mounted panels which convert solar energy to electrical energy.

Solar thermal – Typically rooftop panels which convert solar energy to thermal energy.

ToU Tariffs – Electrical tariffs which vary depending on when energy is consumed.

EXECUTIVE SUMMARY

The proposed North East Cambridge (NEC) development will be situated just south of the A14. The land (about 182 hectares) is currently made up of unused car parking spaces as well an employment area providing 15,000 jobs. It is proposed that the site be transformed to provide 8,000 homes, 3 new schools, community spaces plus 10,000 additional jobs. The aim is for an inclusive, walkable, low carbon new city district to be developed. WSP were appointed to develop and Energy and Infrastructure Study for this site as well and an Energy Masterplan.

The baseline energy consumption for the was calculated as being **61,954 MWh** per annum with a diversified peak of **15.7 MW**; an undiversified peak of 19.7MW was also calculated. This is before the application of any additional technologies and utilising the agreed building fabric and services strategy (which are over and above current minimum requirement sunder Building Regulations).

The following renewable technologies were considered as part of this work:

- **Rooftop Photovoltaics** were found to reduce annual remand, but not affect the peak and generation did not coincide with maximum demand.
- **Ground Source Heat Pumps** (as well as other types of heat pumps including those which use water or sewage) were found to reduce winter peak significantly.
- **Heat Networks** were not considered viable on the site as a whole, but may be possible to connect us smaller groups of buildings

The following smart technologies were considered as part of this work:

- **Time of Use Tariffs** were found to be beneficial at shifting demand away from peak periods.
- **Battery Storage** and communal charging with car barns was found to be a useful mechanism for shifting demand from peak periods to overnight
- The use of **Direct Current** as an alternative to **Alternating Current** networks, whilst theoretically possible was considered to be impractical for a site like this until smaller trials have been undertaken..

In order to facilitate the level of development envisaged in the Area Action plan the local grid will require reinforcement; four options were considered for this. The preferred option was for **UKPN to deliver the reinforcement works** with the cost borne by the local authority. The lack of certainty around the loads and delivery timetable would mean it is unlikely that an IDNO would be interested in delivering such a project.

The additional cost for the preferred technologies (photovoltaics, time of use tariffs, car barns and ground source heat pumps) was calculated to be **£10-15m over and above the base case** (which includes enhanced building fabric and air source heat pumps); which is likely to be apportioned over several parties including the local authority, developers and third-party investors.

Significant stakeholder engagement with relevant parties including UK Power Networks, Greater Cambridge Planning and key development partners to understand needs and constraints and the potential for innovation. This stakeholder engagement work was separate to the Local Planning Authority's consultation works undertaken as part of the emerging Area Action Plan. The consultees were found to be broadly supportive of the approach with the various landowner representatives open to work collaboratively to deliver shared infrastructure.

1 BACKGROUND AND CONTEXT

The proposed North East Cambridge (NEC) development will be situated just south of the A14. The land (about 182 hectares) is currently made up of unused car parking spaces as well an employment area providing 15,000 jobs. The key tenants at the site include Cambridge Science Park (which covers 60 hectares with the freehold owned by Trinity College Cambridge), Cambridge Regional College, Cambridge Business Park (Crown Estate) and the water treatment plant (Anglian Water).

Cambridge City Council and the South Cambridgeshire District Council are developing an Area Action Plan (AAP) that will be the planning framework for new developments in the area for the next 20 years. The aim is for an inclusive, walkable, low carbon new city district located in North Eastern Cambridge is to be developed. It is envisaged to be a mix of homes, workplaces, services and social spaces that will integrate with surrounding neighbourhoods [1].

The five strategic objectives of the NEC redevelopment are:

- Ensuring a **low environmental impact**, addressing both the climate and biodiversity emergencies
- Creating a **characterful,** lively, mixed-use new district where all can live and work
- Meeting **strategic needs** around housing, economic growth and creating an integrated economy (co-locating employment and housing)
- Providing a **healthy and safe** neighbourhood
- Enabling a physically and socially integrated **community** (including integrating into the adjacent communities)

WSP have been appointed to develop an Energy and Infrastructure Study along with an Energy Masterplan for the Proposed Development.

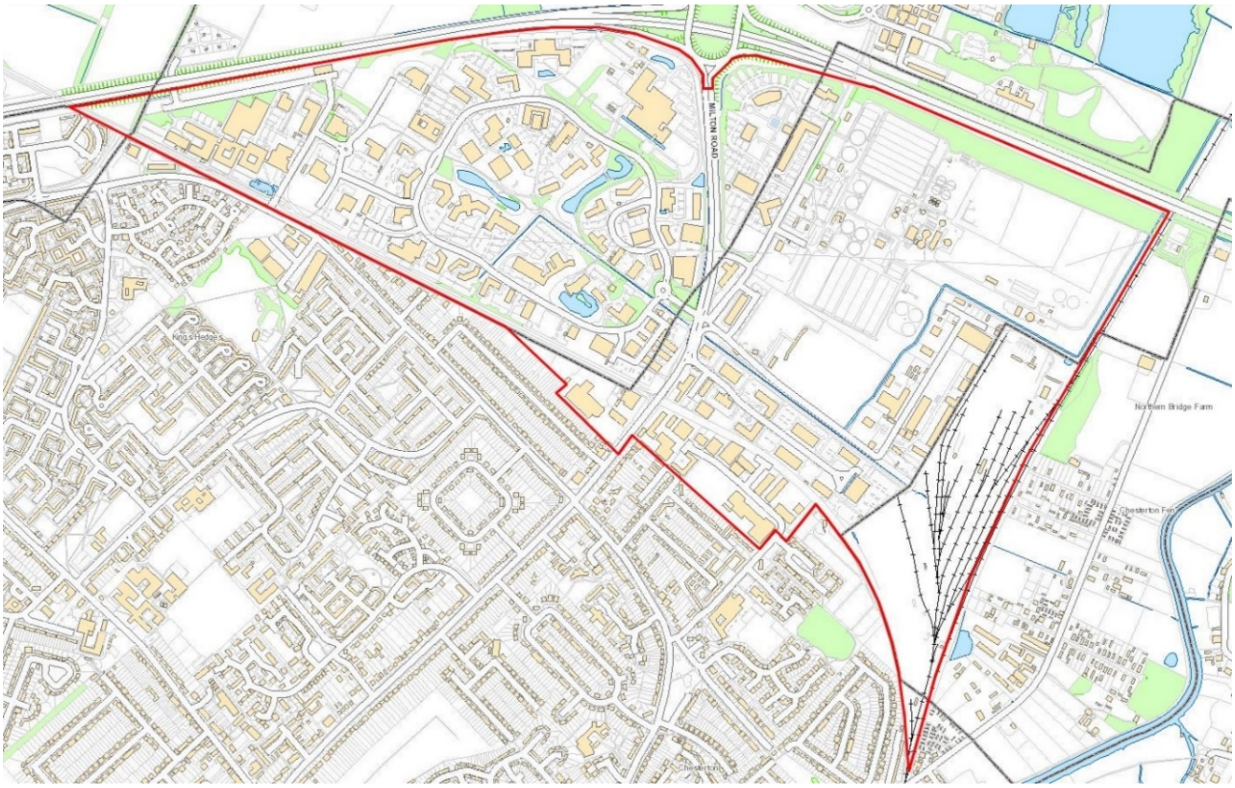
1.1 SITE DESCRIPTION

The NEC site is situated between the A14 to the north and west, the Cambridge to King's Lynn railway line to the east and residential areas to the south. It is bisected by Milton Road which then continues north as the A10 towards Waterbeach and Ely. Milton Road is a key arterial route into Cambridge from the north of the city and NEC therefore lies at a gateway location into the city.

It is proposed that the site be transformed to provide 8,000 homes, 3 new schools, community spaces plus 10,000 additional jobs. The space is intended to be characterised by the amount of green spaces available with walkability / active travel / car free travel all as central themes.

[1] https://www.cambridge.gov.uk/consultations/north-east-cambridge-area-action-plan

Figure 1 - The North East Cambridge Site



2 METHODOLOGY

The following section outlines the methodology of the works undertaken as part of this project. This included the following ten tasks.

The site-wide energy and infrastructure study consists of the following:

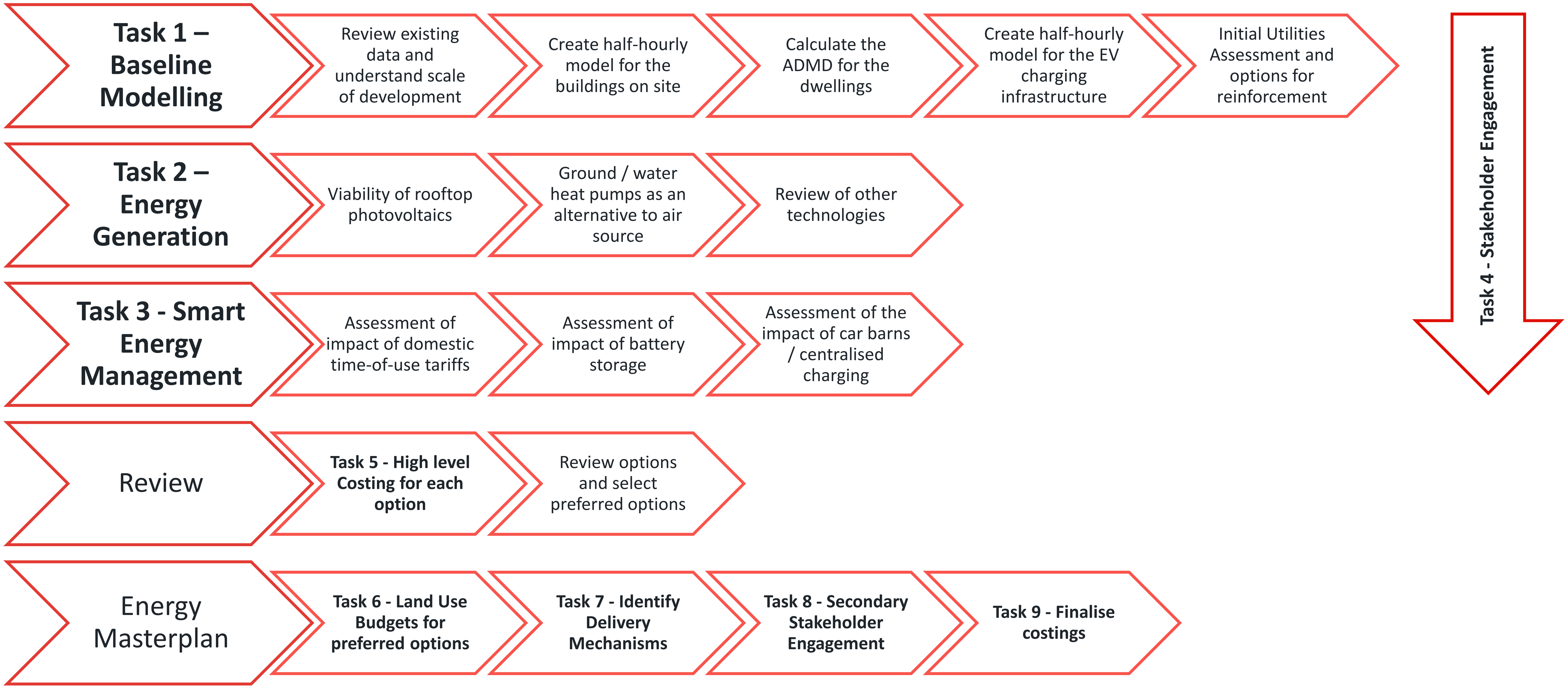
- **Task 1** – Baseline Energy Modelling
- **Task 2** – Energy Generation Feasibility / Viability
- **Task 3** – Smart Energy Management Assessment
- **Task 4** – Initial Stakeholder Engagement
- **Task 5** – Costing of Options

The energy masterplan consists of the following:

- **Task 6** – Spatial Assessments
- **Task 7** – Assessment of Potential Delivery Mechanisms
- **Task 8** – Secondary Stakeholder Engagement
- **Task 9** – Implementation Costs

The methodology implemented in completing these tasks are outlined in the Figure 2 below including relevant sub-tasks where applicable.

Figure 2 – Overall Methodology and Sub-Tasks



2.1 TASK 1 – BASELINE MODELLING

An assessment of the energy infrastructure information already produced for the Infrastructure Delivery Plan, supplementing with additional modelling where required. Additional modelling should consider heat, power and transport and the grid infrastructure required, including: • Demand profiles for heat, power and transport across the NEC site including its temporal distribution across 24 hours, weekly and annually to better understand seasonal impacts; • The uptake of both EV charging and other technologies that may be required to support the decarbonisation of transport; • Different on-site demand management scenarios to optimise storage for heat and power across the site.

2.1.1 UNDERSTANDING THE DEVELOPMENT

Based on the information available within the Area Action Plan and consultation documents[2] the following schedule of accommodation shown in Table 1 was derived. This is the current framework position which will evolve before a preferred strategy is finalised; this will therefore affect final quantum and subsequently load distribution and energy demand.

Table 1 – Schedule of Accommodation

Element	Type	Quantum	WSP Assumptions
Non-Domestic (total 275,150m^2)	R&D / Offices	234,500m^2	
Non-Domestic	Industrial	9,300m^2	
Non-Domestic	Storage	18,150m^2	
Non-Domestic	Schools / Community	13,200m^2	
Domestic (total 8,000)	1 Bed Flat	2,255	~53m^2 each
Domestic	2 Bed Flat	3,829	~78m^2 each
Domestic	3 Bed Flat / Houses	1,322	~93m^2 each
Domestic	4 Bed Flat / Houses	594	~120m^2 each

2.1.2 CREATE HALF-HOURLY MODEL FOR THE BUILDINGS ON SITE

The first task was to develop an energy model for the Proposed Development. This was created to simulate the energy consumption over a typical year at a half-hour resolution. This was undertaken using dynamic thermal simulation software (IES Virtual Environment) to simulate the building loads; assumptions around floor area and typology were made where required. Again, information from the

[2] https://www.greatercambridgeplanning.org/media/1252/typologies-and-development-capacity-assessment-2020.pdf

AAP was used to understand the density and building types for the NEC site. The models created were based on typical recent new projects as shown in Figure 3.

Figure 3 – IES Models (top-left flats, top-right houses, bottom-left school, bottom-right industrial)

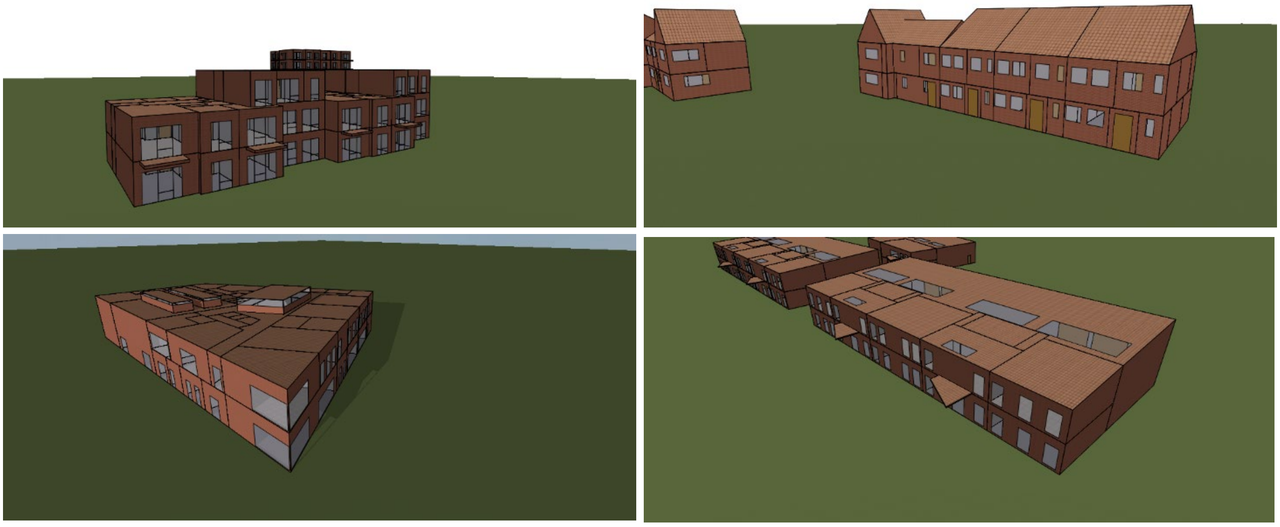
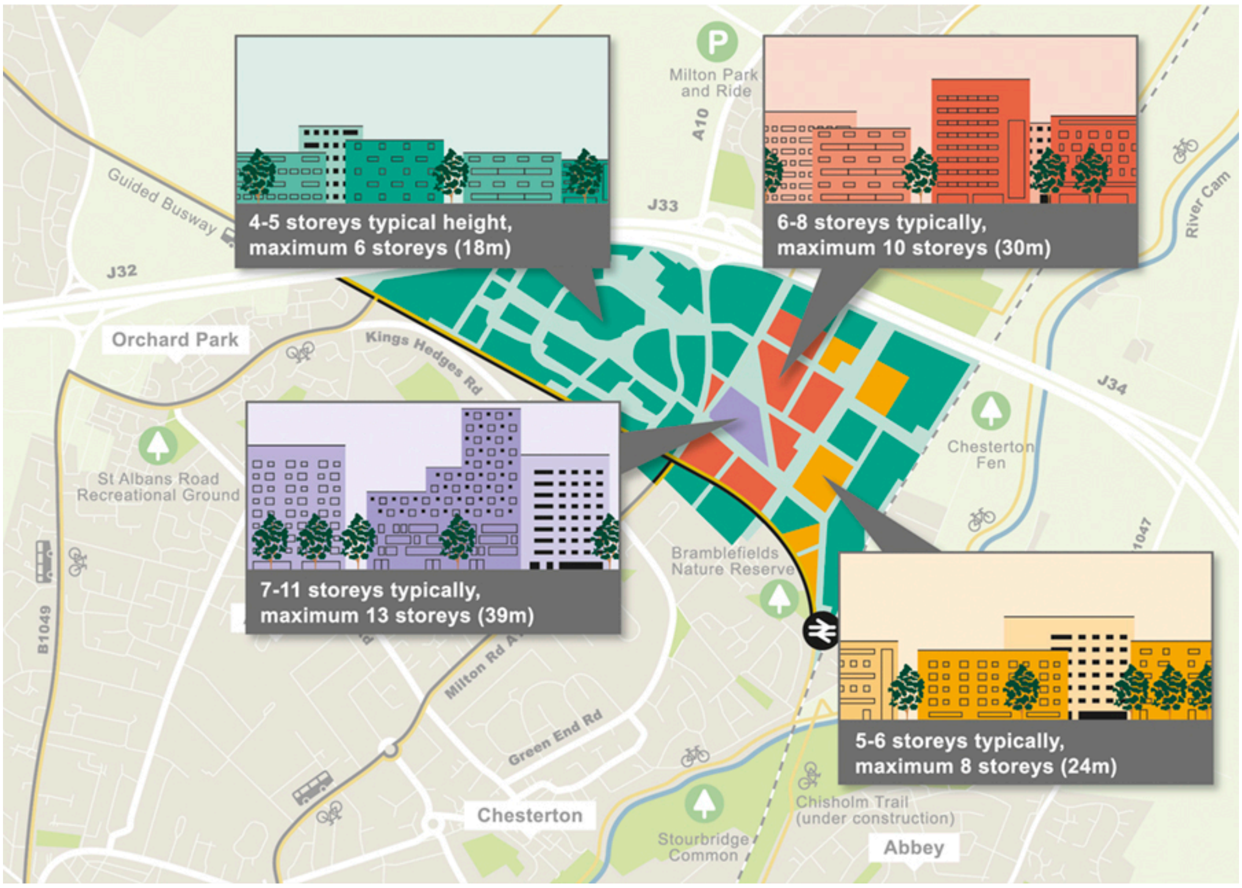


Figure 4 – Building Heights



Data were received from Bioregional & Etude to understand the proposed specifications which may apply to this development as part of their work on zero-carbon homes for the council. Further details of the building specification assumptions agreed can be found in **Appendix A**.

Table 2 – Modelled Building Specifications

Element	Type	Building Fabric	Building Services
Non-Domestic	R&D / Offices, Industrial, Storage	▪ As per current Part L[3]	▪ Air Source Heat Pump (ASHP) ave. CoP of 2.8 ▪ LED Lighting
Non-Domestic	Schools / Community	▪ Building Fabric: Enhanced - As proposed by Bioregional / Etude[4] ▪ Building Fabric: Low levels of air permeability ▪ Building Services: Mechanical Ventilation and Heat Recovery	▪ Building Services: Air Source Heat Pump (ASHP) ave. CoP of 2.8 ▪ Building Services: LED Lighting
Domestic	All Dwellings	▪ Building Fabric: Enhanced - As proposed by Bioregional / Etude[5] ▪ Building Fabric: Low levels of air permeability ▪ Building Services: Mechanical Ventilation and Heat Recovery	▪ Building Services: Air Source Heat Pump (ASHP) ave. CoP of 2.8 ▪ Building Services: LED Lighting

2.1.3 CALCULATE THE ADMD FOR THE DWELLINGS

After Diversity Maximum Demand (ADMD) is a concept used in the design and specification of electricity distribution networks. When considering a single dwelling, the theoretical peak electrical load can be considered at the sum of the maximum draw from each electrical component (fridges,

[3] https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l
[4] The work undertaken by Bioregional / Etude / Currie & Brown was set against Part L 2013 building regulations as a baseline; which was the only national standard available at the time of the work. Since then a new interim uplift to Part L in 2021 and an indicated outline specification for the Future Homes Standard changes to Part L from 2025.
[5] The work undertaken by Bioregional / Etude / Currie & Brown was set against Part L 2013 building regulations as a baseline; which was the only national standard available at the time of the work. Since then a new interim uplift to Part L in 2021 and an indicated outline specification for the Future Homes Standard changes to Part L from 2025.

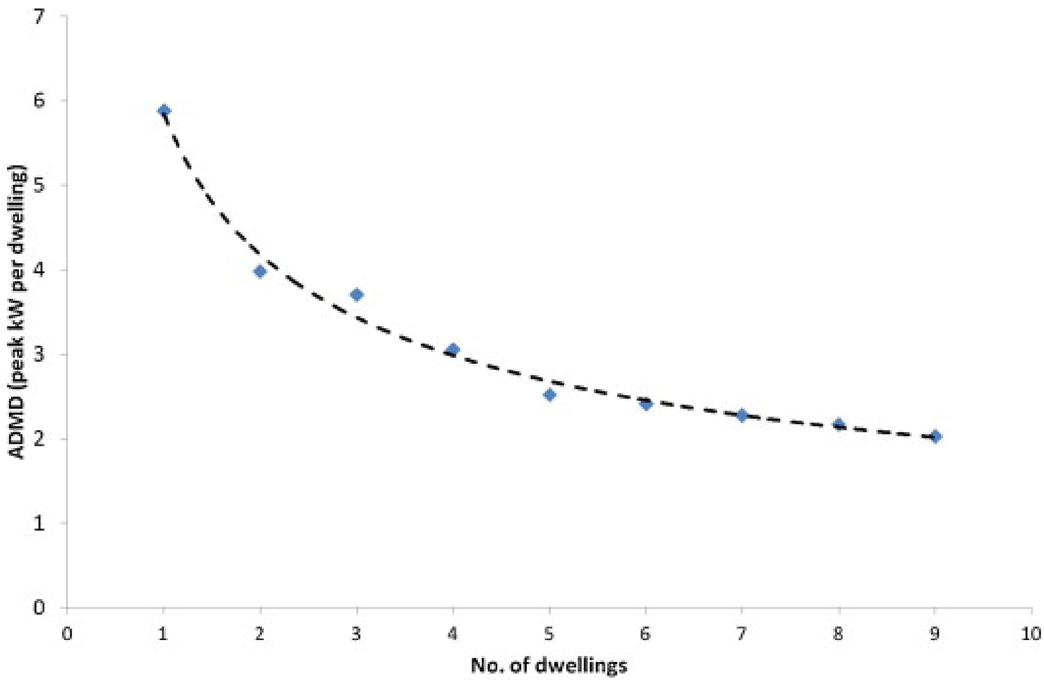
kettles, washing machines, televisions etc.); this in itself may be in the order of several kW. However, it is highly unlikely that all of these electrical components will be operating at any one time and as such the actual peak load in operation is typically much less than this.

Similarly, when aggregated over several homes a 'diversity' factor can be applied to consider the natural variation of the way homes are used. Therefore, the electrical capacity required to power several homes is actually less than sum of the peak demand of each home (where demand is aggregated over a large number of customers). For example, while 10 homes may have peak demands of 6 kW each, it is highly unlikely that the combined demand will ever be 60 kW.

This diversity effect is commonly referred to as After Diversity Maximum Demand (ADMD) and is illustrated in the image below. While a single dwelling has a peak electrical demand of 6kW, the ADMD for nine dwellings is closer to 2kW; therefore, the peak demand for the nine dwellings taken as a whole is only 18kW. Generally speaking, the shape of the curve below is typical for all developments and the more the number of dwellings added to the network, the lower the ADMD, though the ADMD will plateau after a certain point. ADMD values are an overestimation of the coincident peak load a network is likely to experience over its lifetime**. It is currently recommended that diversity not be applied to non-domestic loads and therefore the outputs from IES can be taken directly.**

Whilst the diversity of a traditional development (with gas-fired heating) is straight-forward to calculate, one with heat pumps is less so.

Figure 5 - ADMD for 1 to 9 Dwellings (Gas-Boiler Heated) [6]



By applying diversity to load calculations, smaller peak capacity requirements can be specified resulting in significant cost savings. For a large enough population (such as the 8,000 homes being

[6] *Synthesising electrical demand profiles for UK dwellings.* **Jenkins, D P, Patidar, S and Simpson, S A.** s.l. : Energy and Buildings, 2014, Vol. 76.

proposed at NEC) if assumed to be gas heated, the ADMD would be expected to stabilise at around 1.5kW per property, though this value would not apply at the development at NEC.

The building specification being proposed would imply that the ADMD for the dwellings at the NEC site would likely be higher than a gas heated dwelling, but lower than a heat-pump heated property built to current building regulations. As such a bespoke calculation would be needed.

The ADMD for the Proposed Development has been calculated from three sources; by reviewing existing standards across DNOs, reviewing literature and theoretical models and through WSP's project specific modelling works.

The approach undertaken by each DNO is summarised in Table 3. Not all DNOs currently have a set methodology for considering heat pump-heated properties; for several the calculation will be undertaken on a case by case approach. WSP's utilities team regards Northern Powergrid's approach as the most developed and use their standards for projects throughout the UK.

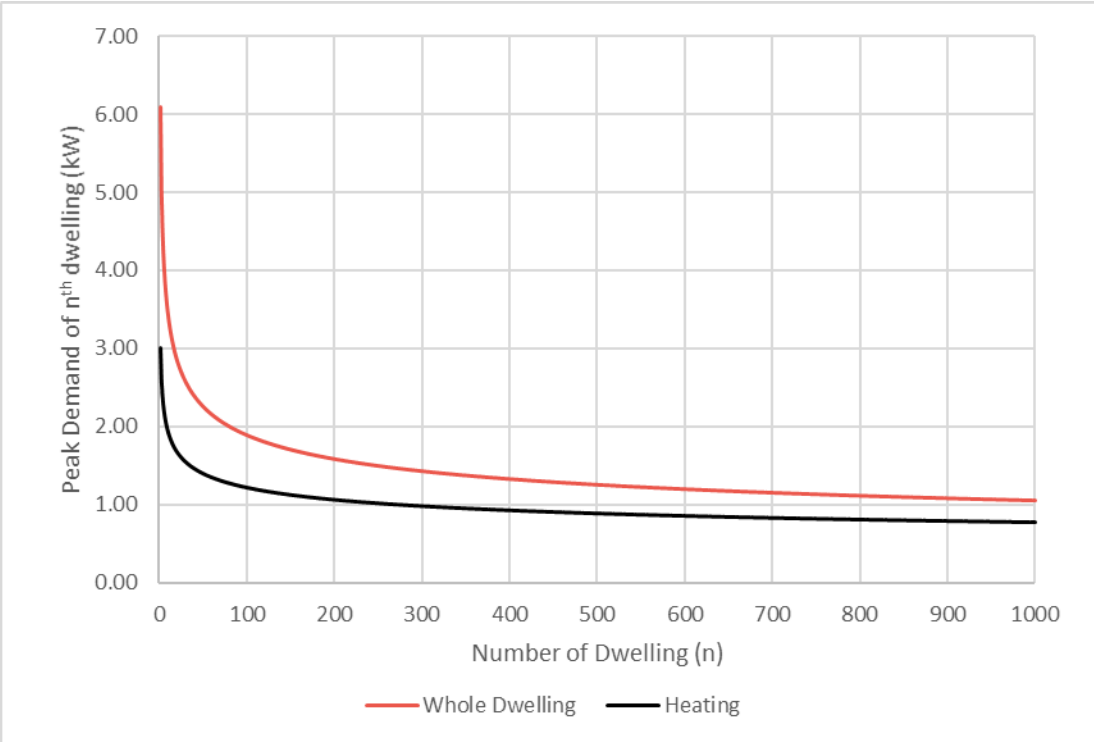
Table 3 – DNO Approach Summary

DNO	1-Bed gas	2-Bed gas	3-Bed gas	4-Bed gas	Ref	1-Bed heat pump	2-Bed heat pump	3-Bed heat pump	4-Bed heat pump	Ref
Scottish and Southern	1.2	1.8	2	2.25	Link					
SP Energy Networks	1	1	1	1.5	Link	2	2.4	2.8	4	Link
Electricity North West	1	1	1	1.4	Link					
Northern Powergrid	1.3	1.3	1.3	1.3	Link	1.4	1.4	1.4	1.4	Link
Western Power	0.9	1.3	1.7	2	Link	1.9	2.7	3.5	4.5	Link
UK Power Networks	1.2	1.2	1.5	1.8	Link					

An ADMD curve based on Northern Powergrid's data was used. By establishing the contribution from the heat pump alone to the overall peak demand, and the relative peak of an NEC dwelling with respect to a regular dwelling, a value was determined.

In addition, separate analysis based on the energy modelling individual dwelling profiles was undertaken to provide further certainty on the final results.

Figure 6 - Northern Powergrid Analysis



2.1.4 CREATE HALF-HOURLY MODEL FOR THE EV CHARGING INFRASTRUCTURE

An energy model was developed for the predicted electric vehicles (EV) at the site. Charging profiles were obtained from the National Grid's Future Energy scenarios and multiplied out by the number of vehicle parking spaces proposed for the site.

Element	Type	Quantum	WSP Assumptions
Parking (total 10,090)	Employment	6,090 spaces	All EV charging ready
Parking	Residential	4,000 spaces[7]	All EV charging ready

Figure 7 – Residential - Weekly Charging Profile

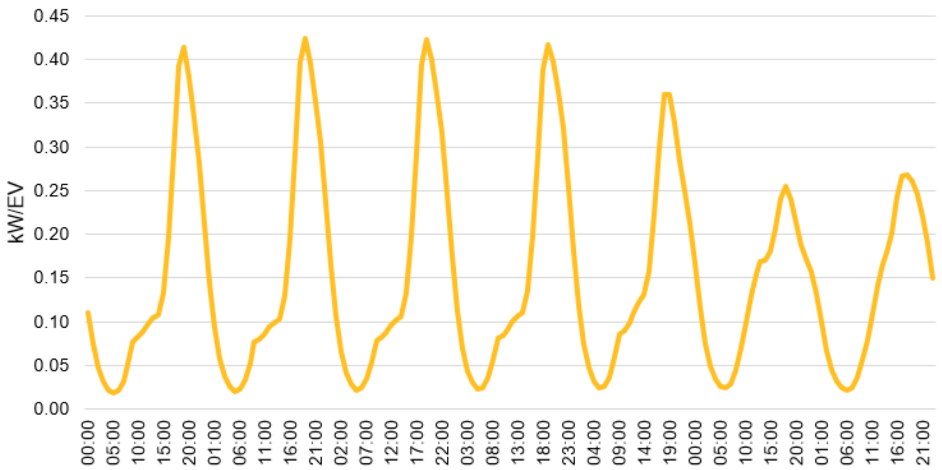
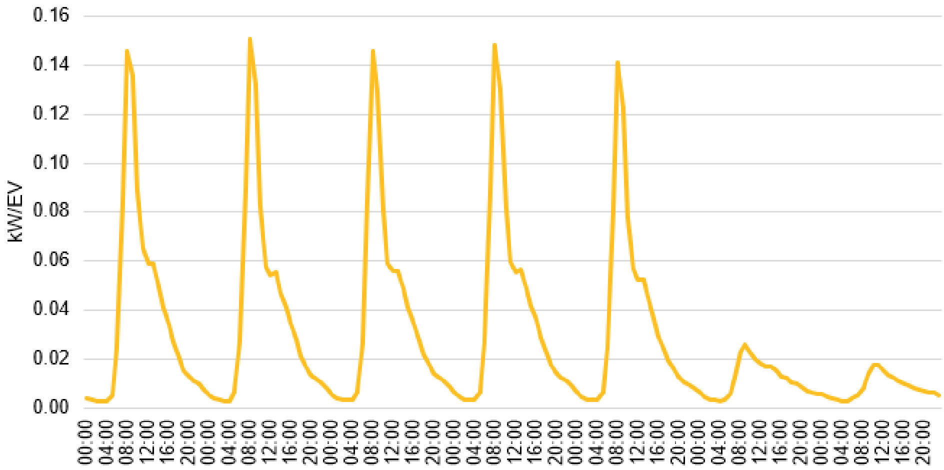


Figure 8 – Work Location - Weekly Charging Profile



A challenge for this analysis is that charging profiles may change, probably to be flatter, as issues such as car sharing increase. Conversely, reducing the number of car parking spaces may drive a

[7] This is the maximum (0.5 per dwelling) and the ambition is to have far less

higher intensity usage of each vehicle, as they are shared across a household(s). This will need to be tracked as the development is built-out.

2.1.5 INITIAL UTILITIES ASSESSMENT

Following the initial estimate for the peak electrical demand for the Proposed Development, an assessment of the current electrical infrastructure was undertaken. See **Appendix B**.

The Distribution Network Operator (DNO) responsible for the network where the site is located is UK Power Networks (UKPN); specifically, the site falls within the Eastern Power Networks licence area. Assessments of the substations currently feeding the site were undertaken, current capacity and spare capacity available to the Proposed Development. See **Appendix C** for the list of substations considered. Long Term Development Plans and Future energy Scenarios were reviewed to understand how the demand at the substation is predicted to change.

Options could then be prepared to provide additional capacity where needed and improving network efficiency. The options considered include:

- UKPN delivers reinforcement work required at Milton Road substation funded by applicant.
- Using Independent Distribution Network Operator (IDNO) to recoup initial investment.
- Deploying battery solutions to reduce need for additional grid capacity.
- Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider.

2.2 TASK 2 – ENERGY GENERATION

The identification of the energy generation and distribution opportunities across the NEC site including the consideration of the feasibility and viability of approaches to ensure that development at NEC supports the transition to net zero carbon by 2050. Consideration has been given to emerging work on Net Zero Carbon being developed in parallel as part of work on the Greater Cambridge Local Plan.

The technologies considered as part of this assessment include the following:

- **Photovoltaics** - Rooftop solar used to generate electricity and offset demand.
- **Ground / Water Source Heat Pumps** - Closed or open loop heat pumps, as an alternative to air source (which is the default). These are considered for more efficient and therefore reduce electrical demand. Location is considered ‘favourable’ for open loop by the British Geological Society, with a concealed aquifer less than 50m from surface.
- **Battery Storage** - To be used for maximising self-consumption and demand shifting

The following technologies were considered less favourable (but not necessarily excluded from the site if viable for a specific building or plot):

- **Solar Thermal** - Can be used to offset demand for domestic hot water. But will compete for space with photovoltaics and so considered less favourable due to practical complexity for integrating into heating systems for the property types considered here. May be suitable for hotels, gyms or other property types with larger domestic hot water demands.
- **Biomass** – Can be used to generate heating and domestic hot water. The technology is not currently supported by central government due to air quality impacts in urban locations. There is

also increasingly concern around whether or not biomass can be considered a sustainable source of renewable energy given issues around sourcing materials.

The following technology has been specifically excluded from this site:

- **Micro-wind** – Can be used to generate renewable electricity year-round but not recommended in urban locations and close to tall buildings as are being proposed here.

2.2.1 PHOTOVOLTAICS

An estimate of the available rooftop area was calculated for the site based on the domestic / non-domestic floor space, average number of storeys, assumptions of the usable rooftop area and the area required per kWp of solar based on the different roof types (flat or pitched). Once an estimate of the maximum capacity of solar was made, modelling was undertaken using industry standard software (PVSyst) to assess the annual generation and create an hourly profile. This was then used to offset the site energy consumption figures to understand the potential for reducing peak demand.

- **Orientation**: a third south, a third south-east, a third south-west
- **PV Spacing:** 10m^2 per kW for flat roof (panels 15° from flat), 7m^2 per kW for inclined roof (panels 30° from flat)

2.2.2 GROUND/WATER SOURCE HEAT PUMPS

For the baseline, an air source heat pump was assumed which had a coefficient of performance with varied with external air temperature (but nominally 2.8). For the ground / water source heat pump option, the efficiency was assumed to be static at a value of 3.5 year-round. As such the system would have more of an impact at reducing winter peak electrical demand but would also reduce overall demand.

2.2.3 HEAT NETWORKS

Based on the initial modelling of the thermal demand of the buildings, the thermal density was calculated on a site wide level as well as on a plot by plot level. The number of units of each type within a plot was multiplied by their respective thermal demand; this was then divided by the plot area to calculate the thermal density for each plot.

2.3 TASK 3 – SMART ENERGY MANAGEMENT

An analysis of the role of smart energy systems including consideration of whether the area is capable of complete independence from grid power and heat (but not an energy island) through the development of a smart grid approach. Consideration should also be given to opportunities for energy storage (both heat and electricity) and the spatial implications of this.

The technologies considered as part of this assessment include the following:

- **Time of Use (ToU) Tariffs** – Using this mechanism to shift demand away from peak times where grid may be otherwise constrained. Whilst there may also have a small reduction in annual electrical demand as a result (which isn't considered here), the main benefit is in demand shifting in when electricity is consumed.

- **Energy Storage** – To be used to either store excess energy generation, (e.g. from solar) for use later in the day or as a method of smoothing energy demand.
- **Car Barns** - To be used as a form of demand shifting.

Consideration was also undertaken for the use of **Direct Current (DC)** as an alternative to Alternating Current (AC) within the dwellings. Transmission of electricity is almost universally undertaken globally using AC in order to reduce losses on the network and for other practical considerations. AC is however considered more dangerous than DC.

Within homes, some appliances operate in DC (as is the power generated from photovoltaics). Therefore, it stands to reason that providing power to homes in DC would not only be safer but reduce losses associated with converting power within devices.

The difficulties around this option, whilst theoretically possible, revolve around the practicalities. As household appliances include electronic equipment to convert 230V AC to DC, these would all need either rewiring or replacing with suitable alternatives (which are not widely available). Power will still need converting from AC to DC before entering the homes, and so there will be losses associated with this. Therefore, whilst this option may be interesting as at a one-off trial at the site, it is currently impractical to propose this option for the development as a whole.

2.3.1 TIME-OF-USE (TOU) TARIFFS

The effect of Demand Side Response (DSR) and Time of Use (ToU) tariffs on domestic energy consumption patterns is still considered difficult to predict. There are a number of recently published studies which point towards the potential impact:

- **Octopus Energy** - The results from their Agile Octopus half-hourly time of use tariff have been published. 28% of users showed a statistically significant change in peak time usage, dropping peak usage from 16% to 11.5% of their daily consumption. Overall, peak use was reduced by 28%, suggesting that wider uptake of smart time of use tariffs could significantly shift overall demand at peak times. However, the opt-in nature of this tariff meant this was a self-selecting user base with relatively engaged consumers. [8]
- **Customer-Led Network Revolution** – This study from 2013 indicated a 10% reduction in evening (4pm to 8pm) peak demand. [9]
- **UK Power Networks** - Energywise recruited social housing tenants living in part of East London to participate in a trial involving smart meters, energy efficiency devices and Time of Use Tariffs/rebates. The results showed a 5.2% reduction in average evening peak demand per participating household. [10]

A reasonable approach based on this evidence was considered to be assume a 10% shift in domestic demand from the morning and evening peaks. As the user base becomes more familiar with ToU

[8] https://octopus.energy/blog/agile-report/
[9] http://www.networkrevolution.co.uk/customer-trials/domestic-customer-trials/%ef%bf%bctime-of-use-tariffs/
[10] https://innovation.ukpowernetworks.co.uk/projects/energywise/

tariffs and artificial intelligence automates smart energy management, this peak reduction is likely to grow.

2.3.2 ENERGY STORAGE

The modelling of the benefit of site-wide energy storage, (excluding hot water) involved the idealised scenario where the battery could be used for predictively 'peak-lopping' the demand. For the modelling the battery is assumed to charge overnight between midnight and 7am and then discharge during the course of the day and flatten any peaks in an optimal manner.

2.3.3 CAR BARNS

A key feature of a smarter energy system is the ability to minimise peak demand and network congestion, allowing the use of cheaper, low carbon generation to be maximised. The current electricity system has been designed to meet a peak in demand between 17:00 and 20:30. For the rest of the day there can be large amounts of underused generation and network capacity. Generation during these off-peak periods is usually cleaner and cheaper. EVs can support the transition to a smarter energy system by, for example, charging overnight (during the off-peak) reducing the need for investment in infrastructure, but also provide power back to the grid (in effect becoming an energy storage solution in their own right). This makes it cheaper for people to charge and integrates EVs into the electricity system in an affordable way. [11]

What will help to achieve that at NEC is that there is an intention that the vast majority of electric vehicles will be stored communally offering the opportunity to control charging times and rates to reduce peak demand, whilst still offering vehicle owners charged cars when needed. For example, charging vehicles overnight between midnight and 7am and see demand shifted away from high demand periods between 4pm and midnight.

2.4 TASK 4 – INITIAL STAKEHOLDER ENGAGEMENT

Engagement was undertaken with relevant stakeholders including UK Power Networks, GCP and key development partners to understand needs and constraints and the potential for innovation.

Engagement was undertaken with relevant stakeholders including UK Power Networks, Greater Cambridge Planning and key development partners to understand needs and constraints and the potential for innovation. This was undertaken concurrently with the other tasks in order to ensure availability.

This included:

- UK Power Networks
- Bioregional / Etude

[11] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/817107/electric-vehicle-smart-charging.pdf

- Stantec

Calls were also set up with the following land owner representatives:

- Core site - City Council/Anglian Water land – Town, Max Fordhams, Pell Frischmann
- Cambridge Regional College - IT and Estates lead at Cambridge Regional College
- The Crown Estate (Cambridge Business Park) - Waterman Group
- Cambridge Science Park - Hilson Moran
- Brookgate - Noveus

This stakeholder engagement work was separate to the Local Planning Authority's consultation works undertaken as part of the emerging Area Action Plan.

2.5 TASK 5 – ASSESSMENT OF COSTS

An assessment of the costs of energy solutions for NEC including liaison with the consultants carrying out the IDP and Viability Study for NEC to ensure that proposals are considered as part of the wider context of development at NEC.

As part of the previous tasks, high-level costs were provided. During this task, the proposed additional costs were summarised for the combination of measures which are considered favourable and are recommended for the Masterplan.

Budget costs for various were calculated based on either published data sources or from industry experience for projects of this type and scale. For the costs of photovoltaics, fully installed costs for recent large systems (within the past 12 months) were used (£800 per kWp installed); though it is acknowledged that costs for this development will be lower owing to the system being installed at construction rather than retrofit as well as the ongoing falling costs of panels as technology improves.

Costs for ground source heat pumps were based on Renewable Heat Incentive reported costs and represent the additional cost over and above air source heat pump options (which would include cost of ancillary equipment including HIUs and distribution pipework).

The cost of batteries was based on recent reported costs for utility scale projects. Again, the costs for this technology are rapidly falling.

2.6 TASK 6 – SPATIAL ASSESSMENT

Review of the proposed Spatial Framework and Land Use Budgets and relevant supporting documents for NEC AAP to inform the production of a site wide energy masterplan for the site and associated planning policy for inclusion in the pre-submission version of the NEC AAP.

As part of the previous tasks, high-level indications of spatial requirements were outlined. For the proposed technologies to be included within the energy masterplan, the final spatial impact was outlined. For the majority of proposed technologies the approach here was to used industry experience of projects of this type as well as referencing rules of thumb from reference documents where relevant.

2.7 TASK 7 – DELIVERY MECHANISMS

Consideration of the wider delivery mechanisms needed to secure the implementation of the energy masterplan including finance options and the commercial arrangements for the management and operation of the energy systems when built for the identified opportunities.

Research was undertaken and case studies prepared to identify existing commercial and financing models lending themselves to each of the various technologies proposed for the Energy Masterplan.

These were then mapped to identify benefits and level of risk / complexity and a shortlist prepared.

2.8 TASK 8 – SECONDARY STAKEHOLDER ENGAGEMENT

Engagement with relevant stakeholders including UK Power Networks and key development partners to understand needs and constraints and the potential for innovation. This should include a specific workshop with development partners to understand the commercial implications of the energy masterplan.

WSP hosted a virtual stakeholder session to outline the findings and vision for the energy masterplan. This was used as an opportunity to refine the strategy and ensure a cohesive / shared approach going forward.

Again, this stakeholder engagement work was separate to the Local Planning Authority's consultation works undertaken as part of the emerging Area Action Plan.

2.9 TASK 9 – IMPLEMENTATION COSTS

An assessment of the costs of implementing the proposed energy masterplan including liaison with the consultants carrying out the IDP and Viability Study for NEC to ensure that proposals are considered as part of the wider context of development at NEC.

During this task, the proposed costings and proposed delivery mechanisms were finalised.

3 ENERGY AND INFRASTRUCTURE STUDY

3.1 TASK 1 – BASELINE MODELLING

The results of the baseline modelling are summarised below, as annual energy consumption and peak demand figures is shown below. Note that peaks occur at different times so do not sum.

Table 4 – Baseline Energy Consumption (Non-Domestic)

Non-Domestic	Type	Total Area	Energy (kWh)	Peak (kW)
B1	R&D / Offices	234,500	23,515,972	9,277
B2	Industrial	9,300	502,277	283
B8	Storage	18,150	1,418,561	276
Other	School / community	13,200	679,056	584
Sub-total		**275,150**	**26,115,867**	**9,720**

Table 5 – Baseline Energy Consumption (Domestic)

Domestic	Type	No.	Energy (kWh)	Peak (kW)
Flat	1-Bed	2,255	6,258,342	3,024
Flat	2-Bed	3,829	14,149,285	7,135
Flat	3-Bed / 4-Bed	1,322	5,116,294	3,038
House	3-4-Bed	594	3,435,553	1,736
Sub-total		**8,000**	**28,959,475**	**14,875**

Table 6 – Baseline Energy Consumption (Transport)

Use	Type	No.	Energy (kWh)	Peak (kW)
Work	Parking Spaces	6,090	1,581,903	917
Residential	Parking Spaces	4,000	5,296,604	1,696
Sub-total		**10,090**	**6,878,507**	**1,798**

Table 7 – Baseline Energy Consumption by End User

Type	Energy (MWh)	Peak (MW)
Non-domestic sub-total	26,116	9.72
Domestic sub-total	28,959	14.87
Transport sub-total	6,879	1.80
Site Total	**61,954**	**19.70**

The table below describes the half-hourly peak demand with further context. The median peak electrical demand for the site is 7.55MW and for the majority of the time, the peak demand is less than 10MW (half the annual peak).

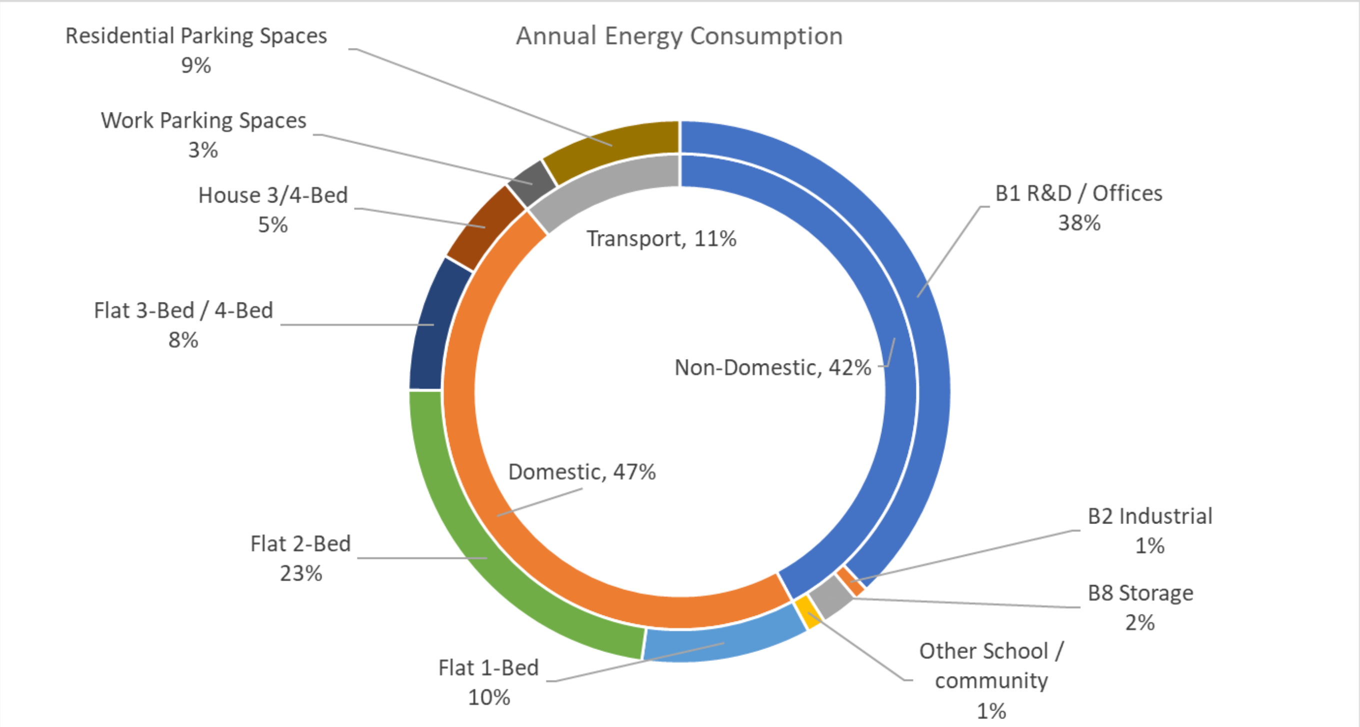
Table 8 – Site Total Demand

	Site Demand (MW)
Min	1.03
Lower Quarter	3.17
Median	7.55
Upper Quarter	9.45
Max	19.70

The figure below shows how the energy consumption is split between the site by end-user type. In addition, we were able to assess the energy consumption by end use:

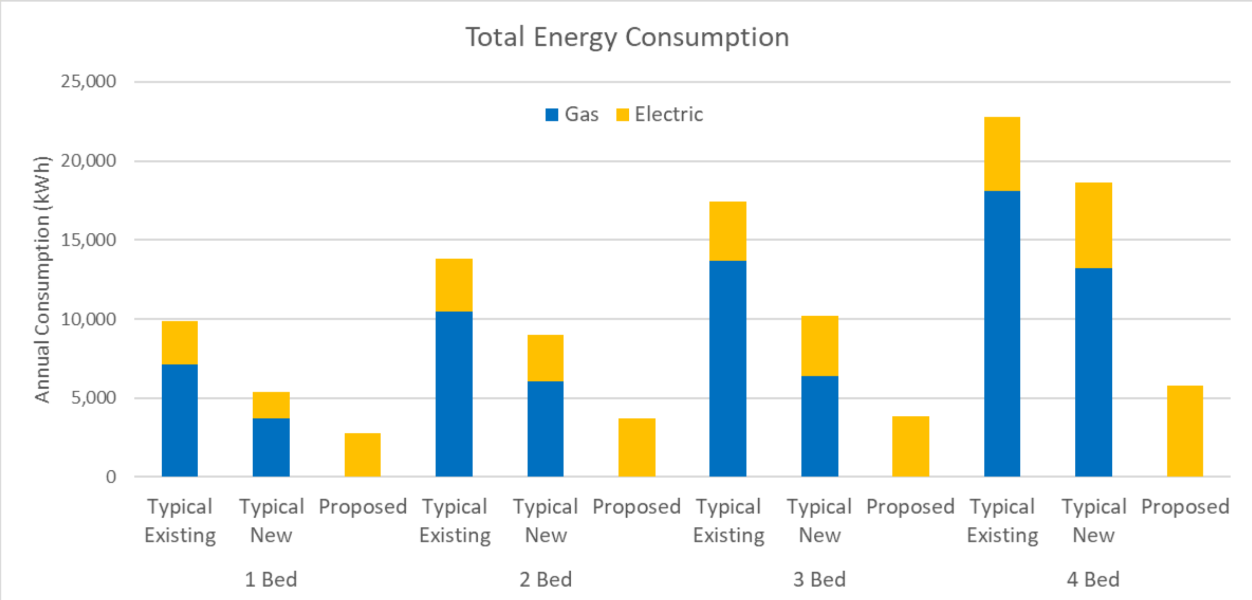
- Equipment – 30%
- Heating and Hot Water – 26%
- Lighting – 19%
- Chiller – 14%
- Fans, Pumps, Auxiliary – 11%

Figure 9 – Site Energy Consumption Split



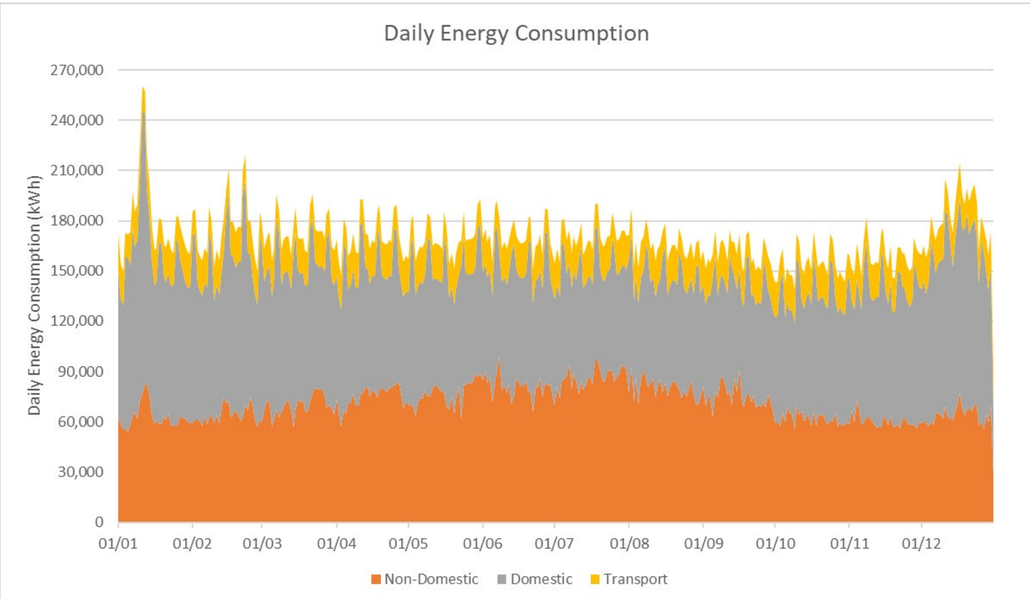
It is also possible to compare the results against what was expected. For an energy efficient building fabric for the dwellings, the energy use is much lower than for a typical development. The total energy demand has been calculated as being in the region of 40-50kWh per sqm, compared to the findings by Bioregional / Etude who developed the specification around the aim of achieving 35kWh per sqm. This variance is likely to be due to the use of different modelling software and building types modelled.

Figure 10 – Dwelling Energy Consumption Comparison



The daily energy consumption (for the base specification) expected for the site is below. For the majority of the year the daily electrical consumption was shown to be between 150MWh and 200MWh; though peaks at 260MWh.

Figure 11 – Site Daily Total Energy Consumption



After Diversity Maximum Demand

For non-domestic buildings, the standard practice is to not consider any potential benefit from diversification of the peak. Therefore, it is assumed that the peak electrical demand is unchanged at 9.7MW. Whilst there will be some intensification and relocation of existing industrial site users, this is uncertain and not captured within this work. Similarly, and due to lack of data, the peak demand for EV charging is assumed to be unchanged. For Domestic properties, the ADMD calculated for a standard gas-heated property is 1.3kW per property (when averaged over the first 1,000 properties) using the Norther Powergrid Calculator[12]; this value is considered the floor value and the ADMD for the heat pump heated dwellings must be at least this value. For a standard heat-pump heated property (which does not have enhanced building fabric) the ADMD is calculated as being 1.4kW per property (when averaged over the first 1,000 properties).

It stands to reason that the ADMD for the dwellings at the NEC site will be between these two values and estimated by WSP based on modelling of the reduced thermal demand, due to the enhanced specification, to be 1.33kW per property. The total diversified peak demand for the dwellings is therefore calculated to be 10.6MW, compared to the undiversified peak of 14.9MW. The total site peak is similarly reduced from 19.7MW to 15.7MW.

The annual energy consumption is unchanged as a result of diversity.

Initial Utilities Assessment

A detailed review of the current capacity of the substation which feeds the site along with Long Term Development Statements (LTDS) and Future Energy Scenarios (FES) can be found in **Appendix C**.

Milton Road Primary substation supplies the NEC site and its surrounding areas. The substation has 2 transformers with a combined rating of 46MVA and firm capacity of 22.1MW. Currently, the peak demand is 15.4MW and 13.1 MW during winter and summer respectively which leaves an available capacity of 6.7MW and 2.8MW for winter and summer.

Projected loads on the domestic, non-domestic and transport sectors of occupants of the NEC site have been produced and discussed above; with the peak demand projected to be 15.7MW. With the current headroom at Milton Road Primary being 6.7MW, there is not enough capacity available to accommodate the site at full completion. For the substation to meet the additional demand, reinforcement works need to be carried out to increase the available capacity and improve the efficiency of the network. The following explores various options that could solve these issues and aid the transition to net zero. It will also provide high level costing and potential financial impact of the solutions.

The four options are:

- UKPN delivers reinforcement work at Milton Road primary substation funded by applicant.
- Using Independent Distribution Network Operator (IDNO) to recoup initial investment.
- Deploying battery solutions to boost network capacity.
- Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider.

Further details on each of these options can be found in **Appendix D**.

[12] http://www.northernpowergrid.com/downloads/3841

Option 1 - UKPN delivers reinforcement work required at Milton Road primary substation funded by applicant.

Reinforcement costs of the 11kV network is taken on by the applicant after accepting the formal offer from UKPN. The costs of works carried out at 33kV are also covered by the applicants whilst the costs at 132 kV are fully met by the DNO. Reinforcement works usually take 2-6 years to be completing depending on the level of works required.

The applicant also has the opportunity to recoup some of the initial investment if another party aims on using the network in the future. In this context, the applicant refers to the individual or company (i.e. developer, local authority, private company, etc) applying for a connection to the public network.

This option involves upgrading the Milton Road primary substation to provide additional capacity to accommodate the NEC site.

To accommodate the extra demand at the site and adhere to the N-1 security of supply requirement, a new 33/11kV 24MVA transformer has to be installed. At present, the substation site doesn't have sufficient ground space to contain a new transformer and this proves to be a limitation. Two options are available; extending the current site via purchase of land adjacent to the site (preferred) or purchase of land across the main road and linking across.

Total Costs (extend existing site): £ 1,385,000 including purchasing of land

Total Costs (adjacent site across main road): £1,924,000

Option 2 - Using Independent Distribution Network Operator (IDNO) to recoup initial investment.

In this case, the IDNO would purchase the equipment used to reinforce Milton Road Primary from the applicant. This leads to the IDNO owning and operating this network and carrying out any future maintenance activities needed.

IDNOs are private developers that have the ability to design, install, own and operate distribution networks located within areas covered by the DNOs. IDNO networks are either directly connected to the DNO network or indirectly via another IDNO's network. IDNOs are regulated in the same way as DNOs although their operating licence doesn't have all the conditions of the DNO licence.

In this option, a new substation similar to Milton Road Primary would be built. Here, the client would utilise the services of an Independent Connection Provider (ICP) to carry out the works needed. The ICP would liaise with IDNO to build this substation to their design requirements and then purchase the assets required.

Upon completion of the works, the IDNO then buys back the assets at market rate which allows the client to recoup part of the initial investment. After the IDNO purchases the assets, the IDNO would then own and operate this part of the network as well as carry out any future maintenance and repair activities. Costs paid to the ICP for the construction of the substation are not recovered.

Total Costs: £2,592,000

Option 3 - Deploying battery solutions to boost network capacity.

UKPN carries out engineering assessments on the grid to identify where battery solutions can be deployed to defer the need for reinforcement works and support network constraint management. This solution focuses more on improving the efficiency of the network rather than adding additional demand.

Deploying battery solutions onto the grid provides the opportunity to provide extra revenue streams by offering balancing services to other parties in the market.

This option involves batteries being deployed to support grid efficiencies which in turn, will free up additional capacity. The batteries will be charged at night where electricity is cheaper, load is low and the grid is not constrained and then, during the daytime when the grid is more constrained, demand can be supplemented by discharging the battery. Using this technology aids to achieve Net Zero as electricity used during the night to charge the battery is mostly from renewable sources.

DNOs in the UK are prohibited from owning or operating energy storage solutions due to market distortions that could result from such activity. DNO ownership could obstruct a competitive market for network flexibility services thus, a third party will be used to provide this service. The third party will be in charge of building, owning and operating the asset and monetising additional revenue streams.

Considering the current headroom available, any energy storage solutions would only be able to complement grid reinforcement and not replace the need for it, as confirmed in the energy storage analysis section.

Total Costs: see energy storage section

Option 4 - Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider.

This option involves an ESCo taking responsibility for all aspects of the utility network, possibly including battery storage, and energy generation.

This option gives the opportunity for each dwelling to have solar PV and a battery serving as its own microgrid. As the NEC site is looking to have low carbon technologies such as solar PVs, ground source heat pumps and battery solutions, this route gives the local council the prospects of setting achievable renewable and CO_2 reduction targets for the site.

An ESCo is different from traditional energy companies as they have the ability to finance/ arrange financing for the project. ESCos guarantee energy savings and the provision of the same level of energy at a lower cost as well as guarantee performance of the service. A certain degree of risk is also taken on by the ESCO for the achievement of improved energy efficiency of the client's facility and have their payment based on the achievement if these energy efficiency improvements.

In this option, the local authority would set up an ESCo and become the utility provider (this does have a precedent but is considered high risk). The ESCo would also negotiate all the utility packages in the same way a master residential developer would for a large residential development. This will enable the local authority to meet its own renewable energy generation, CO_2 reduction targets for the development and other goals set whilst generating a profit from services.

Total Costs: unquantifiable at the moment due level of risk

3.2 TASK 2 – ENERGY GENERATION

3.2.1 PHOTOVOLTAICS

A 11.2 MWp rooftop solar system for electricity generation is estimated as the maximum available for this site. This figure was estimated using the assumptions outlines in the table below.

Table 9 – Site PV Capacity

Type	Area (m^2)	Average No. Storeys	Roof Area (m^2)	Availability [13]	Usable Area (m^2)	m^2/kWp	kWp
Flats	542,283	6	90,381	50%	45,190	10	4,519
Houses	70,053	2	35,027	40%	14,011	7	2,002
B1 - Offices / R&D	234,500	4	58,625	50%	29,313	10	2,931
B2 - Industrial	9,300	1	9,300	50%	4,650	10	465
B8 - Storage	18,150	1	18,150	50%	9,075	10	908
Other - Schools / Community	13,200	2	6,600	50%	3,300	10	330
Total	**887,487**		**218,082**		**105,538**		**11,154**

Modelling was undertaken in PVsyst to estimate the potential energy generation across the site. The results showed that the 11.2MWp would generate in the region of **11GWh** per annum.

When comparing the generation profile against the site-wide energy model, the system is shown to consume over 99% of the energy generated on-site with virtually no excess available for export. In addition, there is no change in the peak electrical demand for the site; this is due to the peak electrical demand occurring at a different time of the day to the generation.

System costs are based on existing installed retrofit costs currently in the market, at £800/kWp for mixed system sizes. The actual costs (if undertaken during the initial construction) may be lower. The cost of panels has fallen dramatically in recent years and will likely continue to fall over the next few years, whilst technology will also improve allowing for potentially a higher capacity system.

Total Costs: £8.9m

PV Case Study - Cambridge Regional College,

In 2015, Cambridge Regional College installed a multi-roof PV system (totalling 200kWp) system to reduce the college's carbon emissions and significantly reduce its energy bills. The system now generates around 182,125 kWh annually, all of which is consumed on site. He system utilises 275Wp panels manufactured by Trina Solar and ABB inverters.

[13] Rooftop PVs will compete with other rooftop plant equipment such as AHUs and ASHPs

3.2.2 GROUND/WATER SOURCE HEAT PUMPS

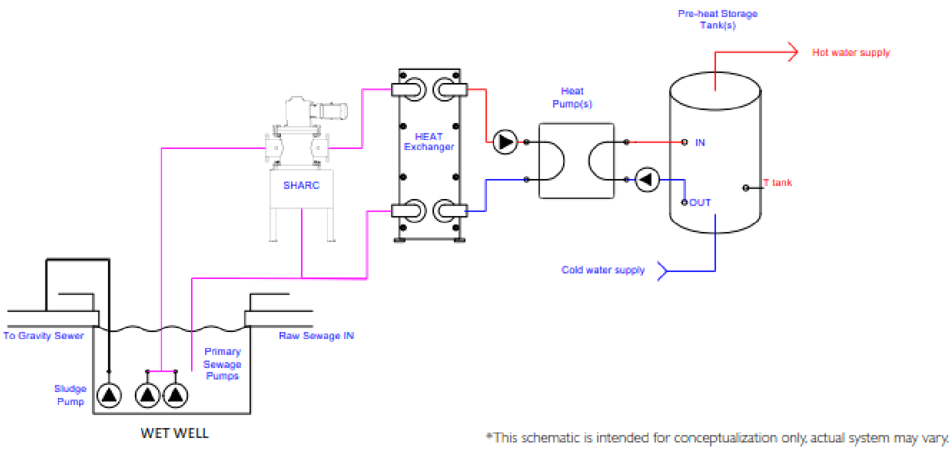
Closed or open loop heat pumps as an alternative to air source, (which is the default), have been considered for the site. These are considered for more efficient and therefore reduce electrical demand, (which in turn reduces the peak demand / need for grid reinforcement).

The location is considered 'favourable' for open loop by the British Geological Society's heat pump screening tool [14], with a concealed aquifer less than 50m from surface. In terms of modelling, the benefit of a ground or water source heat pump would be similar in performance.

The modelling suggests that improving the coefficient of performance from 2.8 to 3.5 as well as benefitting from the fact that air source heat pumps will perform at a lower CoP than that during the colder months will be a significant benefit. The overall reduction in energy consumption is modest at 4.6% owing to the thermally efficient nature of the properties, but the total site peak demand reduction is estimated at 18% (from 19.7 to 16.0 MW). This would not lead to a reduction in the cost for grid reinforcement.

Whilst the focus here has been on the use of ground or water source heat pumps (from an underground aquifer), there are also other heat sources that could be exploited. **The Cambridge Sports Lake** is a planned large water body to the north of the development. Whilst accessing this water body will require crossing the A14, there are at least three separate tunnels which may be used. The lake will be 1.5km from the edge of the development which will pose a problem with the viability of the scheme, which will require agreement from several land owners. As such the overall benefit of the scheme may not be significantly different to that of drilling for an underground aquifer.

Figure 12 – Sewage Source Heat Pump Schematic



Similarly, a **sewage source heat pump** may also be employed which has the potential of higher COPs than a traditional water source heat pump (owing to higher source temperatures). The First Public Drain flows through the site and could potentially be used as a heat source. If this is to be pursued, monitoring of temperatures at the extraction point should be undertaken to assess potential along with a study into the long-term projected change in sewage flow.

Total Costs: £3.4m for GSHP option over and above the cost of an ASHP

[14] https://www.bgs.ac.uk/technologies/web-map-services-wms/open-loop-ground-source-heat-pump-viability-screening-map-wms/

Heat Pump Case Study - New Court at Trinity College

In 2011, the University installed one of the UK's deepest borehole Ground Energy Collector (GEC) consisting of 26 No. borehole heat exchangers, each to a nominal depth of 250m below ground level. The GEC was coupled to a single Climaveneta simultaneous heat pump to provide peak heat output of 246kW, 378kW peak cooling and 355kW simultaneous heating and cooling.

3.2.3 HEAT NETWORKS

Based on the initial modelling of the thermal demand of the buildings, the thermal density was calculated on a site wide level as well as on a plot by plot level. The technical threshold is **30 kWh/m^2** while the practical threshold is considered to be **50 kWh/m^2.**

Table 10 – Heat Network Viability

Area	Total (no.)	Storeys	DPH	Area (ha net)	Thermal Demand kWh	Thermal Density kWh/ha
A	0	4-5	0	25.85	-	-
B	0	4-5	0	4.691	-	-
C	5,500	4-11	175-385	23.238	21,432,757	92
D	120	6-8	330	0.378	417,078	110
E	500	4-6	225-260	3.248	1,741,602	54
F	100	4-5	75	1.855	370,736	20
G	0	4-5	225	1.26	230,126	18
H	500	4-8	225-330	4.766	1,755,084	37
I	550	4-5	225	2.821	2,301,215	82
J	730	4-6	225-300	6.213	2,611,572	42
Sum	8,000			74.32	30,860,170	42

The table suggests that on a site-wide level, the thermal density is too low to be considered viable this is due to the low heating demand for the units owing to the high levels of fabric performance proposed. However, for certain plots, the thermal density may be sufficient to justify small networks and buildings to be connected together. Therefore, whilst heat networks are not viable for the site as a whole there may be a role to play for this technology in certain areas.

The cost of a heat network is estimated to be £150 per MWh[15] for the network itself. On top of this there are additional costs for heat connections (including heat meters and internal piping) which are likely also present for an ASHP solution.

[15]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/424254/heat_networks.pdf

Historically most heat networks utilised gas-fired CHP, would not be possible here and therefore the cost of the heat generator is likely to be higher. To justify a heat network, a heat source to increase the system CoP would be required. This may include the sewage sources or lake mentioned earlier.

Total Costs: £4.6m over and above the cost of an ASHP

Heat Network Case Study - North West Cambridge Development

The development was designed to achieve Code for Sustainable Homes Level 5 for the residential elements and BREEAM 'Excellent' for non-residential buildings. The energy centre incorporates a gas-fired CHP and will provide heat and hot water to all the buildings via a district heating network. The main contract, worth £2.98 million, involved the supply and installation of the main spine of the district heating network for the first phase of the development, which stretched over 2.35km, extending from a central energy centre.

3.3 TASK 3 – SMART ENERGY MANAGEMENT

3.3.1 TIME OF USE TARIFFS (DEMAND SIDE RESPONSE)

The effect of shifting 10% of energy from peak times (both during the morning and evening peaks) were modelled, i.e.07:30-10:30 and 19:30-23:30. The result is a reduction of energy use during these peak periods and an overall reduction in the site peak electrical demand of 7%.

Table 11 – Site Total Demand with and without ToU Tariffs

	Site Demand without ToU (MW)	Site Demand With ToU (MW)	Difference
Min	1.03	1.03	No change
Lower Quarter	3.17	3.62	+14%
Median	7.55	7.52	-0%
Upper Quarter	9.45	9.41	-1%
Max	19.70	18.23	-7%

It has been modelled that 10% shift of peak demand to low peak periods could be achieved primarily through the use of smart meters, at virtually zero system costs due to smart meters being standard. Dependent on consumer engagement, there could also be a reduction in peak demand of around 7%. It may be possible to agree with developers to provide a time of use tariff as standard on the development. Occupiers could change tariffs but would at least start with a TouT and have experience of it.

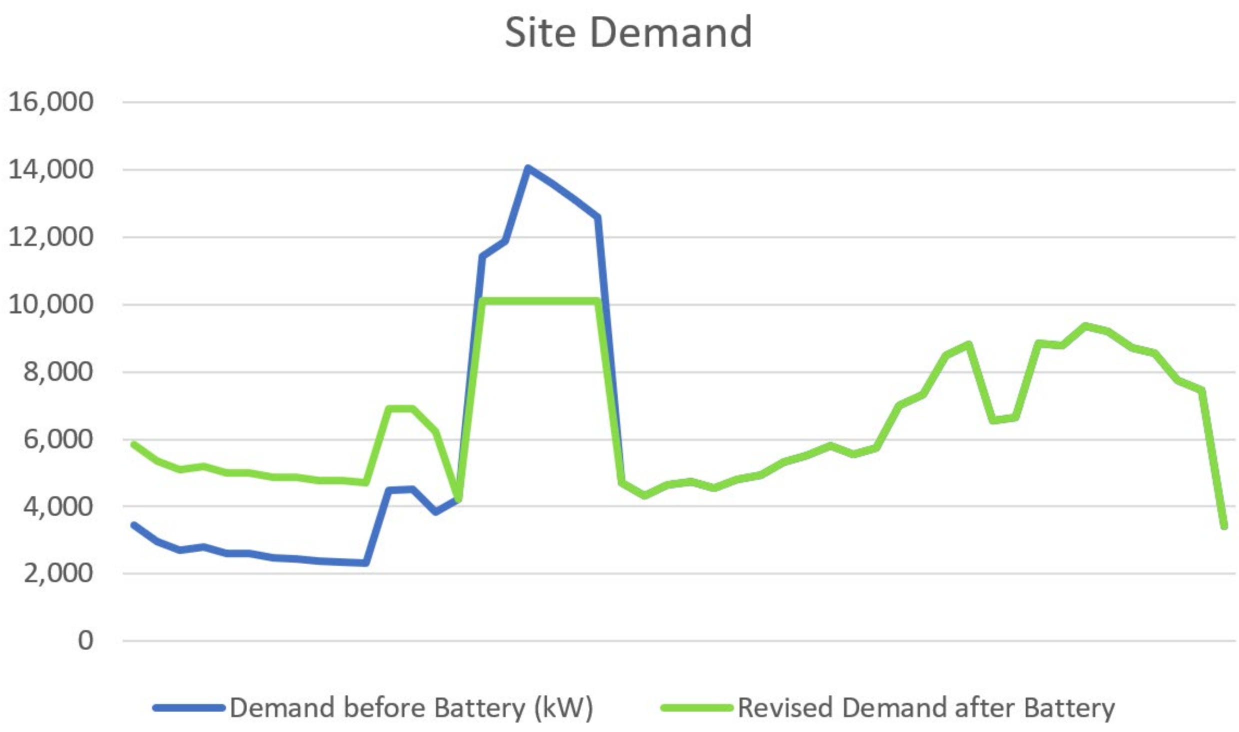
Total Costs: £0 (assuming large uptake of time of use tariffs)

3.3.2 ENERGY STORAGE

Site wide battery storage can be used to mitigate peaks and smooth out demand. It can also be used to store energy at low cost times and discharge at high cost/carbon periods. A 16MWh energy storage device was modelled, equating to 2kWh per dwelling, (a typical domestic scale system),with overnight charging and discharge during peaks assumed.

The results for an idealised peak-lopping system shows a 22% reduction in the peak demand from 19.7MW to 15.3MW

Figure 13 - Site Demand for Typical Day With and Without Battery Storage



The system costs are assumed to be £313 per kWh [16], the cost of battery storage equates to £1.1m per MW saved, significantly higher than the cost of grid infrastructure.

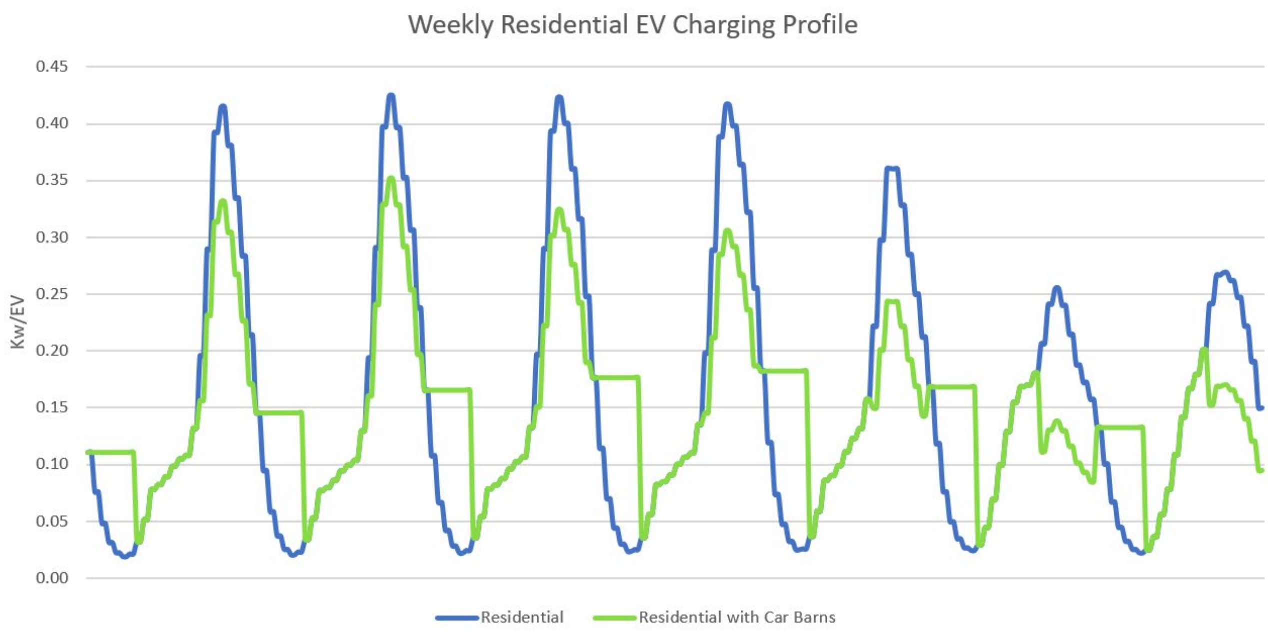
Total Costs: £5m (assuming suitable smart meters are installed as standard)

[16] Based on InterGen project at DP World London Gateway consisting of 320MW / 640MWh lithium-ion battery and costing £200m.

3.3.3 PARKING BARNS

Car barns or communal charging can be used to collectively charge vehicles and have a higher level of controllability as to when this may take place. Similar to ToU tariffs, the aim is to shift demand away from peak times and smooth the demand profiles. As communal parking is already planned, cost would be for the smart management only.

Figure 14 - Weekly Residential EV Charging Profile With and Without Car Barns



The figure above shows the modelled weekly residential EV charging profile both with and without parking barns, assuming a reduction in demand between 4pm and midnight. The results show a reduction in residential EV charging peak of 17%, from 1.7MW to 1.4MW. There is zero resulting reduction in site peak, as reduction does not coincide with site peak demand.

Total Costs: £0 (assuming ground / basement parking will be part of the standard design)

3.3.4 ADDDITIONAL CONSIDERATIONS

The area of peak electrical demand is an area of rapid change due to technology, regulation, customers and even climate. Some of the factors that will need to be tracked over such a long-term development include:

- The Future Homes Standard could reduce domestic demand further, although in the standard indicated in the latest consultation this would not be the case
- Climate change – A warming climate would reduce heating demand and may reach a point where cooling needs to become standard in residential properties.
- Demographics – An ageing population may have differing energy demands and profiles.
- Homeworking changes in light of Covid – The Covid crisis has led to a much greater use of homeworking and delivery of retail goods. How this will affect long-term patterns of behaviour will be important.

- Response to TouT – Time of use Tariffs are still rarely used by consumers, but may become standard in the future, which, along with greater literacy around their use, could make a bigger contribution to peak demand reduction.
- Vehicle Use – NEC is intended to reduce typical car use. Long-term trends towards car sharing and autonomous vehicles could lead to a large change in the charging amount and profile for the development during the build out.

3.4 TASK 4 – STAKEHOLDER ENGAGEMENT

The below is a summary of the key findings from the initial stakeholder engagement exercise.

Table 12 – Initial Stakeholder Engagement

Stakeholder	Comments Raised
Stantec	▪ Assuming the site will be all-electric. But having a small allowance for gas in commercial use if needed as a contingency. ▪ No additional insight into existing energy usage on site or how this might change currently.
UKPN	▪ Last year was the first year they started to produce the Future Energy Scenarios; trying to understand the growth in energy storage, electric vehicles and decentralised energy by speaking to various stakeholders. ▪ Each licence area is doing a bottom up approach to complement the National Grid's top down. Currently working with Element Energy who have a model with different archetypes to consider take up rates. Publishing results in December with graphical overview. ▪ Data they have is on a MSOA basis, so not to the granularity needed on this project.
Hilson Moran (Cambridge Science Park)	▪ There are plans to build around existing car parks and work towards improving the poor connectivity and poor energy efficiency at the moment ▪ Will be undertaken as a process of rejuvenation and heavily refurbishment of buildings, over a period of 20+ years; replacing certain buildings and infilling gaps ▪ Further phases will include hotels, leisure and retail. ▪ Infrastructure in the form of waste, digital, water and energy all require considerable work
Max Fordham/Town (Core Site)	▪ Heat networks not a first preference but are interested in sewage source heat pumps. Having an all-electric development with EV charging and DSR are all elements they are keen to explore further. ▪ Interesting in what the commercial arrangements may be for EV charging and car barns. What are the products / investment at this scale. ▪ Raised thoughts about the need for cooling in dwellings and overheating in homes with respect to future climates. ▪ With long terms increases in working from home questioned how this may affect demand profiles.
Cambridge Regional College	▪ During the last few months, they have closed down a number of buildings and have provided the gas consumption for the last 24 months. ▪ Broadly in agreement with what was presented and the plans, but no plans to electrify or go green at the moment themselves. They already have much of the technologies considered (early adopters) and have issues with biomass (reliability), and solar (long payback). ▪ Raised concerns about parking spaces and lack of park and ride serving the site.

Noveus (Brookgate)	▪ Generally, in agreement about being all-electric and the technologies assumed, building fabric etc. ▪ Very interested in how it will be delivered and how much assistance will be given to developers and how developers can work together. ▪ Also raised concerns about spatial issues associated with some of the options and how this can be fairly apportioned.
Waterman (Crown Estate)	▪ Currently working on upgrading their site to provide high quality office space, though are currently on hold due to the pandemic. They expect demand for these types of properties not to change at this location. ▪ The Crown estate have significant sustainability aspirations for the site, which will feed into their work, however they are keen to only replace equipment towards end of life. ▪ New buildings / retrofits to aim for high BREEAM rating and will likely be a phased approach staring in the next 2-3 years at the earliest as leases expire.

3.5 TASK 5 - ASSESSMENT OF COSTS

The tables below summarise the additional (extra/over) costs for each of the technologies considered in this section, compared to the base scenario which include air source heat pumps.

Table 13 – Technology Costs Summary

Technology	Peak Demand Reduction	System cost (e/o)
Baseline	0%	£0m
Photovoltaics	0%	£9m
Ground Heat Pumps	18%	£3.5m
ToU Tariffs	7%	£0m
Battery Storage	22%	£5m
Car Barns	0%	£0m

Figure 15 – Reduction in Peak Demand by Each Technology

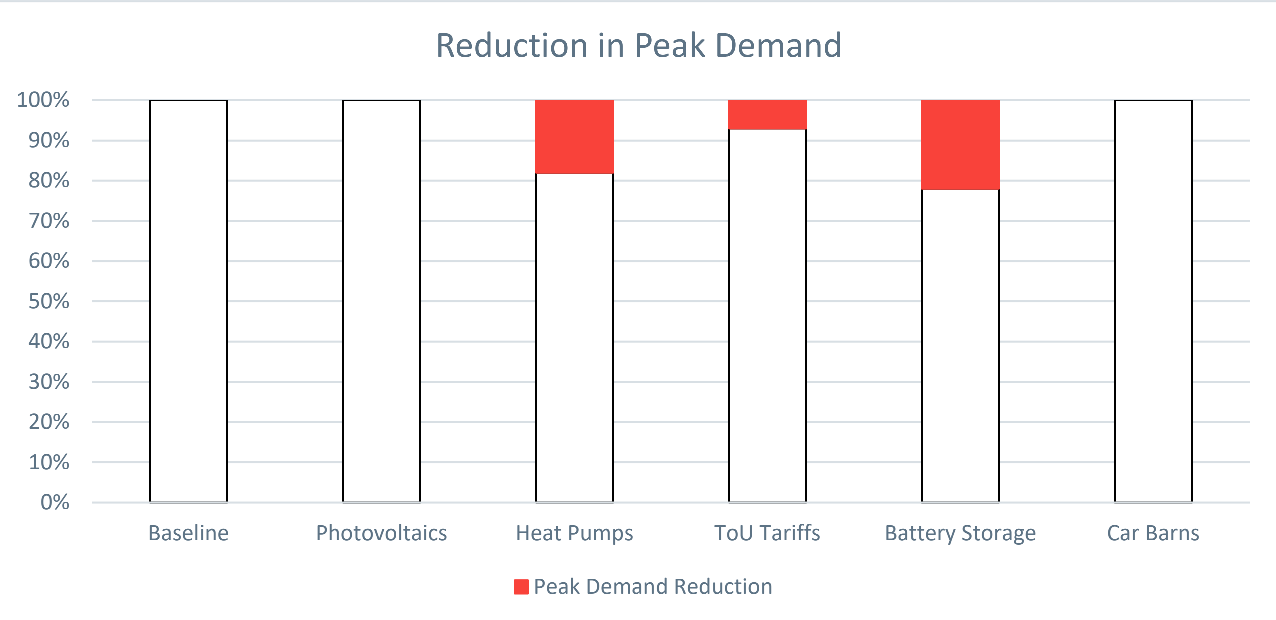


Table 14 – Grid Reinforcement Costs Summary

Options explored	Cost
1. UKPN delivers	£1.4 – 1.9m
2. Using IDNO	£2.5m
3. Deploying battery solutions	£5m – Grid upgrade still required
4. Smart Grid with ESCo	TBC

3.6 RECOMMENDATIONS

The tables below summarise the results of the energy and infrastructure study.

Table 15 – Baseline Summary

Options explored	Capacity	Site Consumption	Site Peak
Baseline	N/A	61.9 GWh	19.7 MWp

Table 16 – Renewables and Smart Technology Summary

Options explored	Capacity	Reduction in energy Consumption	Reduction in Peak Demand
Photovoltaics	11.2MWp	11.1 GWh	None
Ground / Water Source Heat Pumps	N/A	2.9 GWh	18%
Heat Networks	Not viable site wide	None	None
Time of Use	10% of residential demand	None	7%
Battery Storage	16MWh	Small Increase	22%
Car Barns	100% of residential	None	None

Table 17 – Grid Connections Summary

Options explored
1. UKPN delivers reinforcement work required at Milton Road primary substation funded by applicant.
2. Using Independent Distribution Network Operator (IDNO) to recoup initial investment.
3. Deploying battery solutions to boost network capacity
4. Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider

The technologies preferred for inclusion are:

- Photovoltaics
- Car barns
- Time of use tariffs

The technologies which could be included where they are commercially beneficial:

- Ground / water source heat pumps (or potential sewage source) including heat networks

The preferred method for grid reinforcement is:

- UKPN to deliver reinforcement work required at Milton Road primary substation funded by applicant.

The tables below summarise the sites final energy consumption following the selected technologies which results in a 7.6% reduction in peak demand and 18% reduction in annual demand.

Table 18 – Selected Technology Summary

Options explored	Capacity	Site Consumption	Site Peak
Baseline	N/A	61.9 GWh	19.7 MWp
Photovoltaics	11.2MWp	-	-
Time of Use Tariffs	10% of residential demand	51.0 GWh	18.2 MWp
Car Barns	100% of residential	-	-

4 ENERGY MASTERPLAN

4.1 TASK 6 – LAND USE BUDGETS FOR PREFERRED OPTIONS

4.1.1 PHOTOVOLTAICS

As photovoltaics will be located on rooftops, these will not have any impact on land use budgets.

4.1.2 CAR BARNS

The vast majority of the residential development will consist of medium to high rise flats. These are expected to include ground / basement level parking and as such will be included within the building footprint. It is expected that no additional car barn structures will be required as part of the residential development especially in light of the aspirations for low ratios of parking spaces to dwellings.

For the non-domestic properties, existing car parks will likely be retained and vertically extended (as is currently planned at the Cambridge Business Park. Therefore, there will be no significant impact on land budgets.

4.1.3 HEAT NETWORKS

A site-wide heat network is not being proposed. Smaller heat networks may be viable, but this may be on a plot by plot basis in which a small energy centre may be needed.

The size of the energy centre will be highly dependent on the technology employed; an air source heat pump may need in the region of 80sqm [17] of area per MW thermal capacity, whereas an energy centre housing a ground or water source heat pump would be significantly less than this.

It is expected that buildings may choose to connect up to form small networks in which case energy centres may be incorporated within the buildings and potentially ASHPS located on rooftops.

4.1.4 GROUND / WATER SOURCE HEAT PUMPS

Closed-loop ground source heat pumps typically including boring down to depth of 100-250m below ground level (horizontal / slinky type systems would not be viable unless in rare cases). These may be drilled within the building footprint or external to the building and may consist of an array of dozens of boreholes. Above ground this are may be used as car parking, green spaces/ parks, walkways or other uses.

For water source heat pumps, boreholes are usually drilled in pairs. For the type of system sizes predicted for this site, there may be one or two extraction borehole and similarly one or two rejection bores located at lease 100m apart. The space requirement for these is therefore minimal.

[17] BSRIA Rules of Thumb – Guidelines for building services

4.1.5 GRID INFRASTRUCTURE

The land use budgets are summarised as per the below

- Option 1a – 390 m^2
- Option 1b – 1,210 m^2

4.2 TASK 7 – IDENTIFY DELIVERY MECHANISMS

4.2.1 BASELINE BUILDING FABRIC SPECIFICATION

The baseline building fabric specification and building services being proposed as part of this development has been adopted from the work being undertaken by Bioregional / Etude. This is a Cambridgeshire wide study with the resultant specification being adopted across the region. This gives two routes for delivery:

a) Being mandated as part of the Area Action Plan

b) Being mandated as part of the Local Plan

In the both cases, this is dependent on the local authority's ability to go beyond national minimum requirements. The Government's response to the consultation on the Future Homes Standard[18] indicated that most respondents were in favour of retaining local planning authorities' flexibility to set standards on the basis that they are best placed to assess local need and viability. Stakeholders argued that the role of the Building Regulations was to set minimum standards and that local authorities should not be prevented from going beyond these, in order to meet their climate change objectives. In response, in the immediate term, the Government will not amend the Planning and Energy Act 2008, which means that local planning authorities will retain powers to set local energy efficiency standards for new homes.

Therefore, whilst currently there are no planned changed in allowing local authorities to set higher standards this may change in the future. The new planning reforms set out in the Planning for the Future white paper will clarify the longer-term role of local planning authorities in determining local energy efficiency standards. The government expects that as we move to ever higher levels of energy efficiency standards for new homes with the 2021 Part L uplift and Future Homes Standard, it is less likely that local authorities will need to set local energy efficiency standards.

Assuming that the local authority will be able to retain their powers to set energy efficiency standards the cost will therefore be incurred by each of the respective developers.

4.2.2 PHOTOVOLTAICS

As with the building fabric, to some extent rooftop solar can also be mandated by the AAP or Local Plan. Currently many local plans (such as the London Plan) define an overall reduction in GHG emissions against a baseline which can be made up of a combination of energy efficiency and renewable energy technologies. Furthermore, it defines a minimum contribution from building fabric

[18] https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings

improvements. Unlike the London Plan, the aim here is to maximise solar potential rather than meet an arbitrary figure. Therefore, there will be a burden on the developer to provide evidence that rooftop solar is maximised (whilst meeting good design practice). As mentioned previously, the solar panels may compete for space with other rooftop equipment and so for some buildings it may not be possible to install this technology.

This also highlights a difference in building regulations across the UK. Within Welsh Building Regulations the 'Notional Building' PV's are assumed with an area of 5.3% of the floor area (up to a maximum area of 50% of the roof) will be applied producing 120kWh/m² each year. The roof area does not play a factor. It is not a requirement to include PVs or any on site renewable technologies within the actual design however the reduction associated with the PVs would need to be offset through improvements made elsewhere in the design.

With the end of Feed-In-Tariffs, the payback model around third-party funded solar systems have changed. Payback is now dependent on offsetting instantaneous electricity demand. Evidence suggests significant subsidy-free growth in commercial / industrial schemes, particularly in direct-wire Power Purchase Agreements (PPAs).

The two delivery mechanisms would therefore be either direct capital investment by the developer or third-party ownership using a PPA.

The supply of electricity to a premise (historically via CHP, but potentially via photovoltaics) generally requires a licence from Ofgem. However, exemptions can apply and can offer landlords the opportunity to sell electricity to residents connected to a site's privately-operated electricity network [19]:

- On-site supply allows self- generated power to be supplied at the same site as generation occurs. No more than 1MW of power can be supplied to domestic consumers, however additional power may still be provided to the premises by a licensed supplier.
- An exemption also exists for small suppliers (who may be supplying to more than one site) if supplying only self-generated electricity and provided that no more than 5MW of power is supplied at any time, of which no more 2.5MW is supplied to domestic customers.
- The distribution of low voltage power is also exempt from the need for a licence if distributing no more than 2.5MW to domestic consumers (or if distributing exclusively to non-domestic customers).

Case Study

A hypothetical scenario where 300 residential apartments with a small amount of commercial accommodation. This site benefits from a zero-carbon heat network powered by a water source heat pump in addition to a small amount of on-site PV generation. An Energy Services Company (ESCo) is responsible for providing heat and electricity to the apartments. Electricity is imported from the grid and resold to the residents by the ESCo.

On-site generation and supply will not, in this scenario, require a licence, as long as the 1MW limit is not breached. However, the majority of power will be purchased from a licensed supplier, imported from the grid and resold (again without the need for a licence) by the ESCo. The resale will be subject to the Maximum Resale Price (MRP) cap and therefore will not be a profit-making

[19] https://content.switch2.co.uk/hubfs/Generating%20%26%20selling%20electricity%20-%20Fact%20Sheet%202020.pdf

activity for the ESCo save for where the power is then used for non-domestic. In practice, the lower cost of buying electricity from the licenced supplier at the bulk meter can still allow electricity to be resold to the residents at a lower price than they can achieve directly from a licenced supplier even when the costs of metering and the maintenance of the distribution network are recovered by the ESCo.

4.2.3 GROUND / WATER SOURCE HEAT PUMPS

Similar to Photovoltaics, the delivery of ground source heat pumps could be encouraged via the AAP. As this could be funded either by the developer or an ESCo, as before.

4.2.4 HEAT NETWORKS

Establishing a district heating scheme involves significant upfront investment on a par with other major infrastructure projects. Scheme development risk can be high and therefore there is a requirement for public sector organisations to work together effectively to produce robust schemes which can attract developers and investors. Typically heat networks are financed by investors, who then operate the scheme and sell heat at a rate below the market but at a sufficient level to make a reasonable return.

The characteristics of heat networks can vary greatly; however, all networks require an appropriate demand for heat, i.e. heat customers to generate revenues. How secure the heat demand is will be a key aspect in assessing the investment risk of the scheme and therefore the financial and commercial viability of the scheme. Heat network projects will progress through a typical project development cycle, from concept, to feasibility, to business case, through commercialisation and ultimately investment. At each stage of the process the economic value of the project, such as investment returns or Internal Rate of Return (IRR), will be assessed and the cash flows that support the economics should become more certain as heat customers are secured and contracted.

The lack of significant anchor loads, and overall thermal demand density suggest a site wide scheme will not be favoured, but localised schemes may be viable and beneficial where a heat source can significantly increase the overall CoP of a heat pump system. Any viable scheme must ensure that all parties (owners, operators, heat off-takers, investors) achieve a financial return.

4.2.5 CAR BARNS

The Department for Transport are currently developing smart charging standards, which will likely affect be in place by 2025. The smart chargepoint regulations will require compliance with elements of the BSI PAS standards for energy smart appliances (specifically PAS 1878), which are currently under development. Once the BSI PAS 1878 is finalised and published (due in early 2021), it is the intention to take forward regulations for compliance with elements of PAS 1878 through secondary legislation under section 15 of the AEV act[20].

[20] https://www.gov.uk/government/consultations/electric-vehicle-smart-charging/public-feedback/electric-vehicle-smart-charging-consultation-summary-of-responses

Historically, there have been a number of routes to delivering EV charging infrastructure[21] including 'loss leader model' (offer free charging to attract drivers), 'cost recovery' (set a usage fee to cover the cost of your charge points) and 'profit making' (set a usage fee that covers your costs and generates profit).

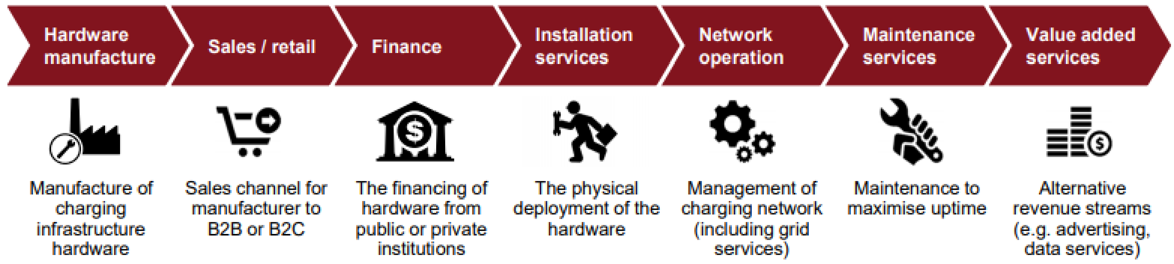
Here, three options for the delivery and operation of the chargepoints are considered:

- Option 1 Council own and operate them all on a site basis, benefitting from peak demand management;
- Option 2 - Third party company operates the whole system;
- Option 3 – Each block to manage itself.

Depending on the model pursued, the council and property developer must ensure that arrangements and funding are in place to cover maintenance and remedial action in the event of accidental damage or vandalism. Even where a chargepoint is provided and fully maintained by a private company, there may be a risk if the company were to cease trading. Any installation will therefore require contingency arrangements in place. See Appendix E for procurement examples.

For the NEC Site, it is expected that the requirement for EV charging infrastructure will be mandated as part of the AAP. The concern here is more around management of the smart charging / Demand Side Response element of the works.

Figure 16 – EV Charging Value Chain[22]



For car barns, an opportunity here is for the network operation management and could include aggregating EV battery capacity and selling services to DNOs. These opportunities are summaries below[23], but several still have issues around their practical implementation:

- Demand Side Response (DSR) – shifting demand as modelled as part of this project
- Frequency Response (FR) – which will require grid-to-vehicle (G2V) and vehicle-to-grid (V2G)
- Energy Storage – storing excess power from renewables
- Balancing services – increasing demand in response to price signals

Case Study – Project Dino (Domestic Infrastructure and Network Optimisation)[24]

This study being undertaken by Energy System Catapult and Evergreen Smart Energy includes the development of a two-way communications solution to allow network operators to

[21] https://pod-point.com/guides/business/ev-charging-business-models
[22] https://www.cornwall-insight.com/uploads/1.%20Adrian%20Del%20Maestro_PWC.pdf
[23] https://www.engage-consulting.co.uk/engage-consulting/the-monetisation-of-ev-charging-assets-for-flexibility-services/
[24] https://evergreensmartpower.co.uk/what-we-do/project-dino/

communicate with certain household appliances (such as EV chargepoints). If the network can warn appliances when the local system is under stress, and the appliances can choose how and when they use electricity, then they can automatically dial down their energy consumption to relieve that stress. Whilst the focus is on car chargers, this technology could also be integrated into heat pumps.

4.2.6 GRID INFRASTRUCTURE

In terms of providing the additional grid infrastructure required to support the development of the NEC site, Table 18 compares the options against the criteria below:

- Financial Viability
- Timescales
- Regulatory and market constraints
- Technological requirements

Table 19 – Grid Infrastructure Delivery Mechanisms Summary

	Financial Viability	Timescales	Regulatory and Market Constraints	Technological Requirements
Option 1: UKPN delivers reinforcement work at Milton Road primary substation funded by applicant.	Applicant must commit to covering all costs before reinforcement works by UKPN can commence.	Approx. 2-3 years.	Little or no regulatory and constraints exist as the cost of reinforcements are met before the project commences.	Reinforcement works required are carried out on already existing components.
Option 2: Using Independent Distribution Network Operator (IDNO) to recoup initial investment.	Applicant must commit to all of the costs before IDNO gets involved.	Approx. 2-3 years.	Reinforcement works needed are carried out by the chosen IDNO.	Components needed already exist.
Option 3: Deploying battery solutions to boost network efficiency.	Battery developer will know the level of income required to support initial capital costs but will still require grid upgrade.	Approx. 2-3 years	DNO has access to third parties to carry out battery requirements in line with Ofgem regulation.	There is available technology to support this solution.
Option 4: Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider	Cost of connection per dwelling will be agreed with the developer and financial modelling of the ESCO will be predetermined.	Approx. 3 years to set up ESCO and acquire infrastructure.	Private electrical wiring is a requirement needed per dwelling.	Assessment of energy demands have to be made to determine what energy infrastructures would be deployed.

4.2.7 SUMMARY OF FINDINGS

A summary of the findings can be found below:

Table 20 – Delivery Mechanisms Summary

Technology	Delivery Mechanisms	Benefits / Limitations	Risk Level
Building Fabric	Local planning requirements	Subject to Planning for Future white paper	Low
Photovoltaics	Local planning requirements / developer	Subject to Planning for Future white paper	Low
Photovoltaics	Third party ownership / operation	Only worthwhile for large systems	Medium
Heat Pumps	Local planning requirements / developer	Subject to Planning for Future white paper	Low
Heat pumps	Third party ownership / operation	Only worthwhile for large systems	Medium
Heat Networks – Infrastructure & operation	Third party ownership / operation	• Overall thermal demand density low • Lack of anchor loads / investment appetite • Some localised opportunities	High
Car Barns - Infrastructure	Local planning requirements		Low
Car Barns - Operation	Council	• Requires a high level of investment and ongoing expertise • Can be difficult for the council to implement without grant funding • Offers the most flexibility	High
Car Barns - operation	Third party	• Would require the property developers to lease land to a 3rd party for the chargepoint installation • Low financial risk to the council • Potential may be limited by the attractiveness of the location and types of chargepoints available • Provision may not match the public need	Medium
Car Barns - Operation	Individual block level	• Low financial risk to the council • Potential may be limited by the attractiveness of the location and types of chargepoints available • Provision may not match the public need	Low

Grid Infrastructure	UKPN delivers reinforcement work at Milton Road primary substation funded by applicant.	• Applicant must commit to covering all costs • Little regulatory constraints	Low
	Using Independent Distribution Network Operator (IDNO) to recoup initial investment.	• Applicant must commit to covering all costs before the IDNO gets involved • Requires a high level of certainty around future energy demands and timescales	Medium
	Deploying battery solutions to boost network efficiency.	• Grid reinforcement will still be required; battery solution not sufficient to cover additional demand	Medium
	Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider	• Financial modelling by ESCO required	High

4.3 TASK 8 – SECONDARY STAKEHOLDER ENGAGEMENT

A secondary stakeholder engagement exercise was undertaken to report back findings and allow for feeding into the final suggestion. All previously consulted stakeholders were invited to the session, with the following attending:

- Bioregional
- Etude
- Hilson Moran
- Max Fordham
- Pell Frishmann
- Stantec
- U + I
- UKPN
- Waterman Group

No objections were raised, and the group were supportive of the approach and recommendations.

4.4 TASK 9 – FINALISE COSTINGS

The tables below summarise the additional (extra/over) costs for each of the technologies considered in this section, compared to the base scenario which include air source heat pumps. This shows the additional cost in the region of £10-15m which is likely to be apportioned over several parties including the local authority, developers and third-party investors.

Table 21 – Costings Summary

Technology	System cost (e/o)
Improved Building Fabric	Within Baseline
Air Source Heat Pumps	Within Baseline
Photovoltaics	£9m
Ground Source Heat Pumps	£3.5m (optional)
ToU Tariffs	£0m
Car Barns	£0m
Grid Reinforcement	£1.4 – 1.9m

5 RECOMMENDATIONS / NEXT STEPS

Improved Building Fabric

The basis of this study was the use of an improved building fabric over and above current Building Regulations (Part L 2013) which also vary from those proposed under the Future Homes Standard. The impact of these measures is a reduced need for grid infrastructure improvements at the development. The building fabric and ventilation systems proposed are close to achieving a space heating demand of less than 15-20 kWh/m^2/yr in line with the recommendations of the Committee on Climate Change on the future of housing.

The enacting of these standards is central to this analysis and it is recommended that these are brought into local planning requirements for the site.

Next Steps

The building fabric and services strategy as recommended in the work undertaken by Bioregional / Etude to be adopted for the NEC site.

Air Source Heat Pumps

An electrified heating system has been proposed for this site; air source heat pumps being recommended by Bioregional / Etude. From 2025, no new dwellings will be able to contain fossil fuel boilers and therefore ASHPs provide a natural alternative. Whilst there are several different types of heat pumps, ASHP can be installed at a low cost and are considered almost universally applicable.

Next Steps

The building fabric and services strategy as recommended in the work undertaken by Bioregional / Etude to be adopted for the NEC site.

Rooftop Photovoltaics

Rooftop photovoltaics is seen as the most viable method of generating renewable electricity on the site. However, the dwelling density of the site plus the presence of other rooftop equipment (such as ASHPs) would mean it is unlikely that there would be sufficient to offset all of the site's electrical demand. It would also make it difficult to mandate a minimum quantum of panels.

Next Steps

AAP to include provision to maximise rooftop PV. Proposal should show how the inclusion of PV has been maximised including practical and operational limitations. It should be expected that all flat roofs as well as inclined roofs (+/-90^o from south) should include PVs.

Ground / Water / Waste Heat Source Heat Pumps

Aside from air source heat pumps, there are a number of alternative typs of heat pumps which may be deployed at the site. Ground source heat pumps are usually more expensive but typically last longer and perform better in colder conditions and therefore would be useful in reducing the peak site electrical demand. Water source heat pumps are also an option for the site (either underground or from a large water body) as is the use of waste heat (from sewage). Exhaust air heat pumps combine the functions of a heat recovery ventilation system with a heat pump that can heat water and provide a limited amount of space heating.

Next Steps

A requirement for all proposals to include a viability assessment for alternative, more efficient heat pump systems, to be included within the AAP.

Time of Use (ToU) Tariffs

Whilst there is a benefit to implementing ToU tariffs, there is no method mandating this. It is thought that long term, this way of charging domestic customers will become the norm. Therefore, the focus should be on ensuring infrastructure is in place.

Next Steps

Mandate the installation of suitable smart meters across the site.

Car Barns

Parking spaces will already be installed within the base case.

Next Steps

Mandate all long-stay parking spaces to include EV charging capability. Local authority to agree operational control of charging and include within tenancy agreements. Controls to be put in place as required potentially on a site-wide level.

Grid Reinforcements

It is recommended that UKPN delivers reinforcement work at Milton Road primary substation funded by the local authority. The investment may be recouped over time from connections, depending on the legal agreements.

Next Steps

The next steps to get connected occur in the following phases:

- **Project Planning Phase**: Here, the DNO or IDNO will be identified and initial contact will be established.
- **Information Phase**: Project specific information is shared with the DNO (or IDNO) to discuss the various stages involved in the development of the project. At this phase, the decision to use an Independent Connections Provider (ICP) to do the contestable works is made.
- **Design Phase**: A formal connection application will be submitted to the DNO with supporting technical information. The DNO makes a connection offer which will be reviewed, discussed and agreed upon then a formal agreement with the DNO and/or ICP will be entered.
- **Construction Phase**: A contract with DNO (or IDNO) begins and construction works for the grid reinforcements will start.

- **Compliance, Testing & Commissioning Phase**: The necessary agreements with the DNO (or IDNO) are finalised and the new works are commissioned.
- **Ongoing Responsibilities**: Regular operational & maintenance responsibilities and tests are carried out to keep the assets in working order. Relationship with DNO (or IDNO) is maintained.

6 NET ZERO CARBON TARGET

The UK Green Building Council outlines two different scopes for a net zero carbon development; one is inclusive of embodied carbon and the other for operation only[25]. The steps required are:

1. Establish Net Zero Carbon Scope
2. Reduce Construction Impacts
3. Reduce Operational Energy Use
4. Increase Renewable Energy Supply
5. Offset Any Remaining Carbon

Similarly, the work undertaken by Bioregional / Etude is more prescriptive and states that net zero carbon can be achieved for this type if the following conditions are met:

1. Metered energy use of 35 kWh/m^2 for dwellings and 55 kWh/m^2 for schools GIA/year or less achieved through energy efficient building fabric, ventilation and heating systems
2. No fossil fuel combustion on site
3. Solar electricity generation that exceeds metered energy use on site

The following section quantifies in a high level the GHG impacts against each of the 5 steps set out by the UKGBC.

6.1 ESTABLISH NET ZERO CARBON SCOPE

For the purposes of this assessment, both construction and operational carbon has been quantified and considered within scope.

6.2 REDUCE CONSTRUCTION IMPACTS

It is beyond the scope of this study to consider how the embodied GHG associated with construction of the buildings can be minimised or reduced. However, a high-level calculation using rules of thumb has been undertaken to give an order of magnitude for the quantity of emissions associated with a typical development of this type.

Using RICS data[26], the embodied carbon is estimated as being:

- 238,300 tCO_2 for non-domestic
- 503,500 tCO_2 for domestic
- **741,800 tCO_2** for the combined domestic and non-domestic (excluding wider infrastructure)

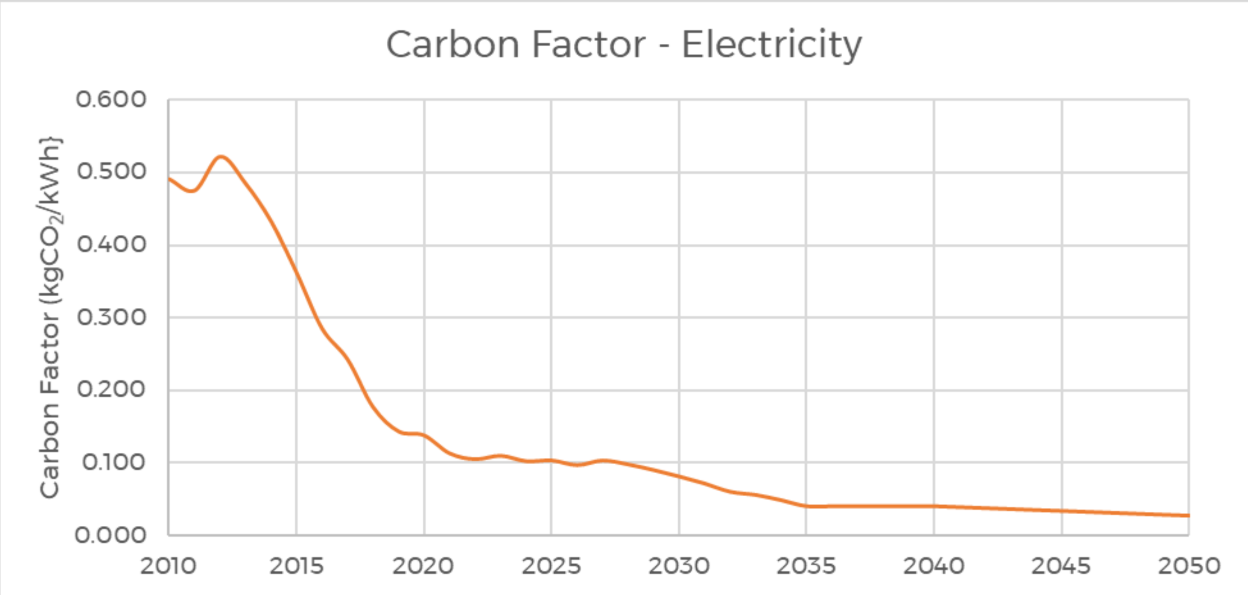
[25] https://www.ukgbc.org/wp-content/uploads/2019/04/Net-Zero-Carbon-Buildings-A-framework-definition.pdf
[26] RICS Professional Information, Methodology to calculate embodied carbon of materials

6.3 REDUCE OPERATIONAL ENERGY USE

The baseline energy consumption for the site is estimated to be 61,954 MWh per annum. The GHG emissions associated with this will vary with time as the grid decarbonises. [27]

- 2,478 tCO_2 in 2040 (assuming 0.040 $kgCO_2$ per kWh)
- 1,673 tCO_2 in 2050 (assuming 0.027 $kgCO_2$ per kWh)

Figure 17 – Decarbonisation of Electricity



6.4 INCREASE RENEWABLE ENERGY SUPPLY

A maximum of 11.1GWh of renewable electricity generation per annum has been proposed for the site. As previously the GHG emissions associated with this will vary with time as the grid decarbonises.

- 444 tCO_2 in 2040 (assuming 0.040 $kgCO_2$ per kWh)
- 297 tCO_2 in 2050 (assuming 0.027 $kgCO_2$ per kWh)

6.5 OFFSET ANY REMAINING CARBON

Following the previous steps, the total amount of GHG offsetting is summarised below:

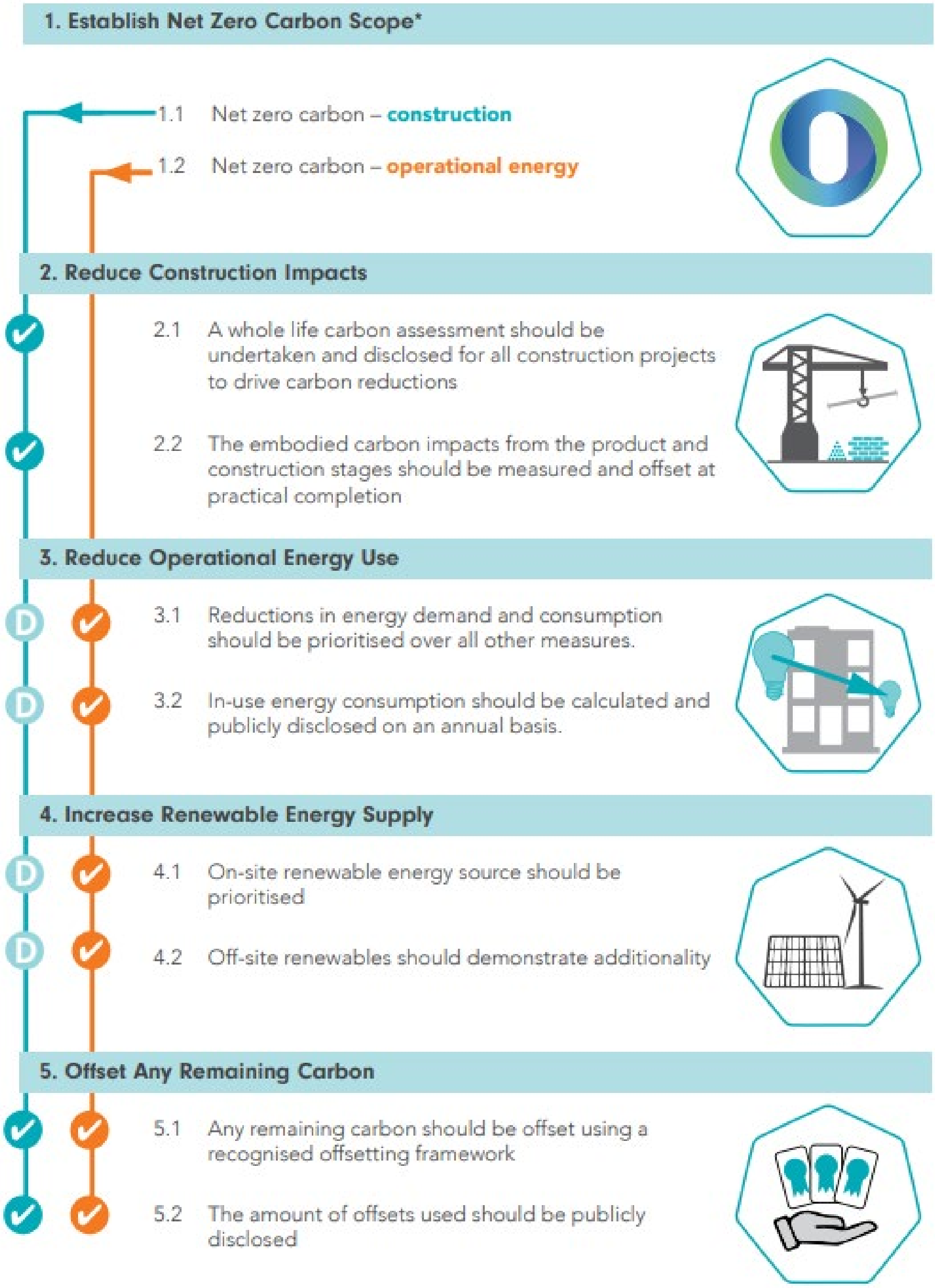
- 742,800 tCO_2 to be offset the construction impacts (one-off)
- 2,034 tCO_2 to be offset in 2040 (projected earliest completion date)
- 1,376 tCO_2 to be offset in 2050 (ten years after completion)

The construction impacts will require offsetting once, whilst the gap between operational energy consumption and renewable energy generation would mean that annually there will be a gap that will need offsetting; this will slowly reduce in time as the grid decarbonises.

[27] Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal

The work being undertaken by Bioregional/Etude suggests that offsetting should play a minimal role, and only where a development cannot meet its needs onsite. In this case, the NEC site is proposed to be a very high-density development with relatively limited roof space and therefore offsetting would be needed.

Figure 18 – UKGBC Net Zero Definition



Appendix A

BUILDING FABRIC SPECIFICATION

The proposed building fabric for new developments to be in line with net zero aspirations (as recommended by the work being undertaken aby Bioregional, Etude and Currie & Brown) are summarised below.

Table 22 – Building Fabric - Dwellings

	Part L1A 2013 Notional	Indicative FHS [28]	Houses	Flats
Floor (W/m²K)	0.13	0.11	0.10	0.16
Walls (W/m²K)	0.18	0.15	0.10	0.16
Roof (W/m²K)	0.13	0.11	0.10	0.15
Windows (W/m²K)	1.4	0.80	0.90	0.80
Air Permeability (m³/hr.m²) @50Pa	5.0	5.0	0.65	0.65
Heat Generator	Gas Boiler	ASHP	ASHP	ASHP
Heat Generator Efficiency	89.5%	280%	280%	280%

Table 23 – Building Fabric – Non-Dwellings

	Part L2A 2013 Backstop	Part L2A 2013 Notional	Schools
Floor (W/m²K)	0.25	0.22	0.15
Walls (W/m²K)	0.35	0.26	0.13
Roof (W/m²K)	0.25	0.18	0.19
Windows (W/m²K)	2.2	1.6	0.95
Air Permeability (m³/hr.m²) at 50Pa	10.0	3.0-7.0	0.65
Heat Generator	Gas Boilers	Gas Boilers	ASHP
Heat Generator Efficiency	86%	86%	280%

28 https://www.gov.uk/government/consultations/the-future-homes-standard-changes-to-part-l-and-part-f-of-the-building-regulations-for-new-dwellings

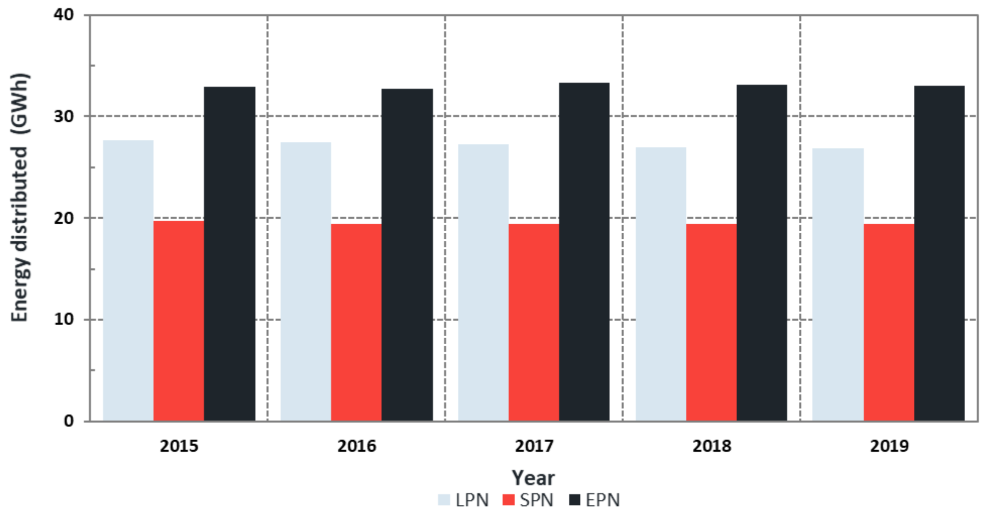
Appendix B

EASTERN POWER NETWORKS PERFORMANCE REVIEW

NETWORK STRUCTURE

Figure B-1 below shows the growth of the number of customers in each license area. From the figure, it can be observed that the Eastern Power Networks (EPN) has the highest number of customers in the UKPN network with over 3.6 million customers in 2019. The London Power Networks (LPN) licence area has the second highest number of customers followed by South East Power Networks (SPN) with 2.35 million and 2.3 million customers respectively

Figure B-1 - Energy Distribution in UKPN Licence Areas



The growth of the DNO's network length respective of each licence area is shown in Figure B-2 below. The EPN licence area has a considerably larger DNO network length of 98,071 km when compared to LPN and SPN license areas which have network lengths of 37,271 km and 53,134 km for the year 2019, respectively.

Figure B-2 - Network Lengths of UKPN License Areas

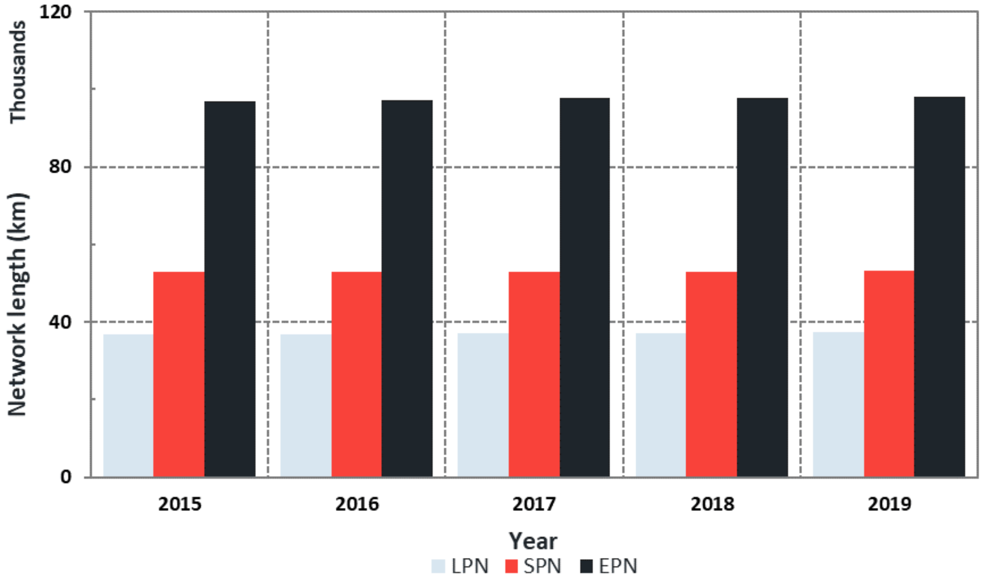


Figure B-3 below shows the amount of energy supplied to customers in the licence areas. In 2019, it can be observed that the EPN has the highest energy consumption due to it having the highest number of customers to serve. Both LPN & SPN have similar amounts of customers but LPN has a much higher energy consumption. This is attributed to the fact that the area is more industrial than the SPN area leading to a higher amount of energy consumed.

Figure B-3 - Energy Distribution in UKPN Licence Areas

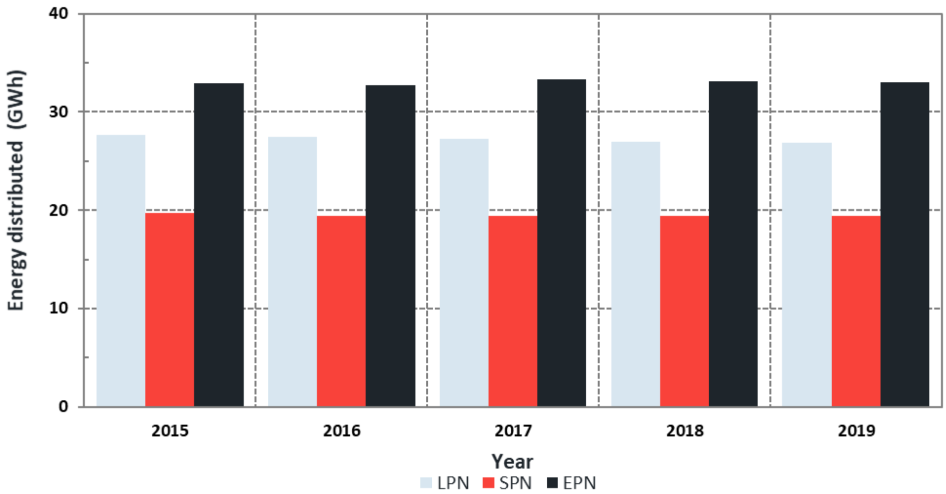
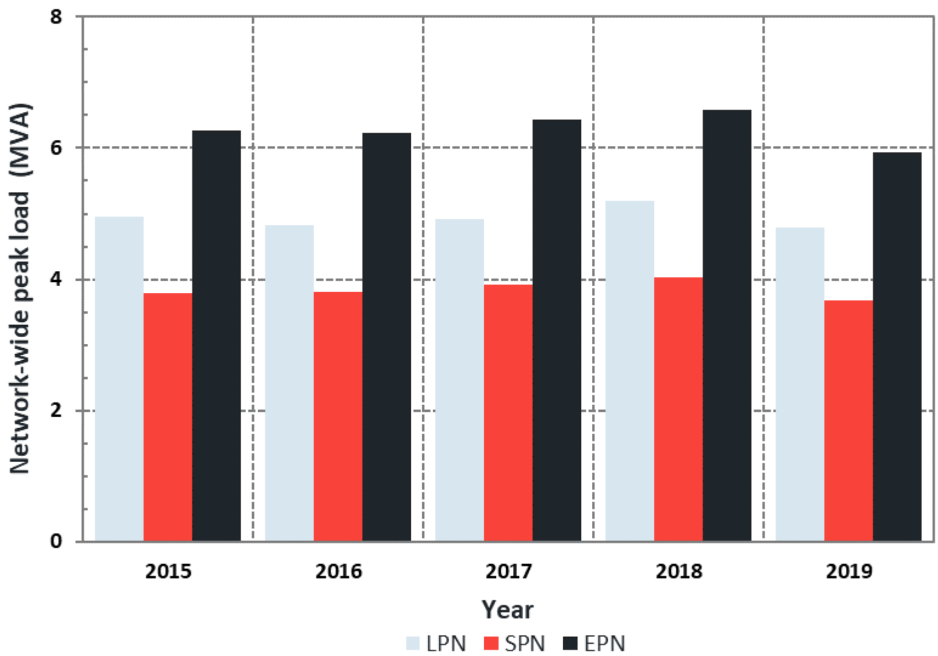


Figure B-4 shows the nation-wide peak load for the license areas. The trend observed for the network-wide peak load distribution is similar to that of the energy distributed in the previous figure. n 2019 the EPN has the greatest peak load with 5.9 MVA due to its customer base. The LPN license area comes in second with a peak load of 4.8 MVA due to the heavy industrial presence in the region followed by SPN at 3.7 MVA.

Figure B-4 - Network-wide Peak Load of UKPN Licence Areas



EPN Performance

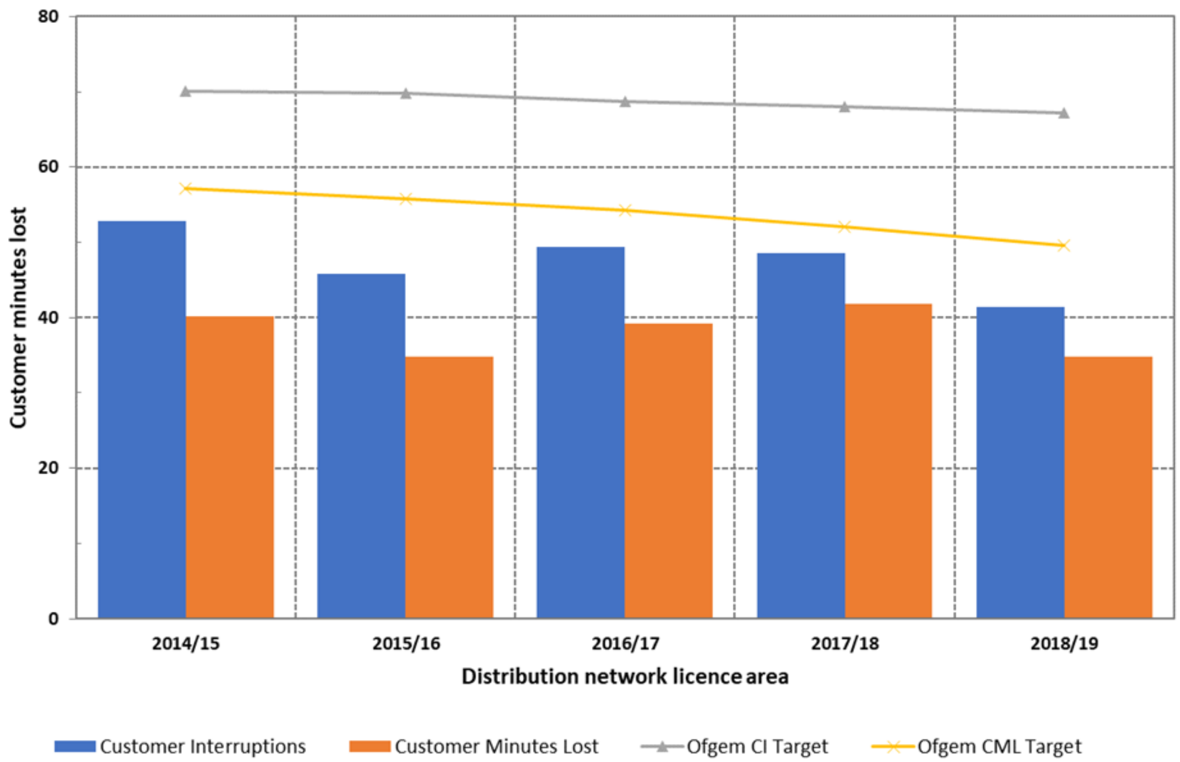
Amongst the three licence areas, the Eastern Power Networks (EPN) will be focused on as the NEC site falls in this area. This licence area spans over the counties of Norfolk, Suffolk & Hertfordshire, most of Cambridgeshire, Essex & Bedfordshire, parts of Buckinghamshire & Oxfordshire and the northern suburbs of the Greater London area. The EPN licence area covers approximately 20,300 square kilometres including 33,434 km of overhead lines as well as 64,637 km of underground cables and serves over 3.6 million customers.

Quality of Service is a key metric that is tracked by the Office of the Gas and Electricity Markets (Ofgem) for each of the DNO's in the country. It is quantified by 2 main parameters; Customer Interruptions (CI) which is the number of customers interrupted per 100 customers on the network and Customer Minutes Lost (CML) which is the average length of time customers experienced no power for 3 minutes or longer.

This metric is important to track as the proposed site is exploring opportunities to connect low carbon technology such as heat pumps and electric vehicles, deployment of energy efficiency measures, etc. Especially with the addition of 8,000 new homes, 3 new schools and 22,000 sqm of industrial floor space, it is important to see the levels of continuity for electricity the licence area provides its customers.

Figure B-5 summarises the reliability performance of the EPN area. It can be observed that the EPN's customer reliability performs well when compared to Ofgem's target. In the 2018/2019-year period, the license area had a CI value of 41.7 which is 38% better than Ofgem's target of 67.2. The licence area also had a CML value of 35 and with Ofgem's target being 49.6, this means that the area performed 29% better.

Figure B-5 - EPN's Reliability Performance Against Ofgem Targets

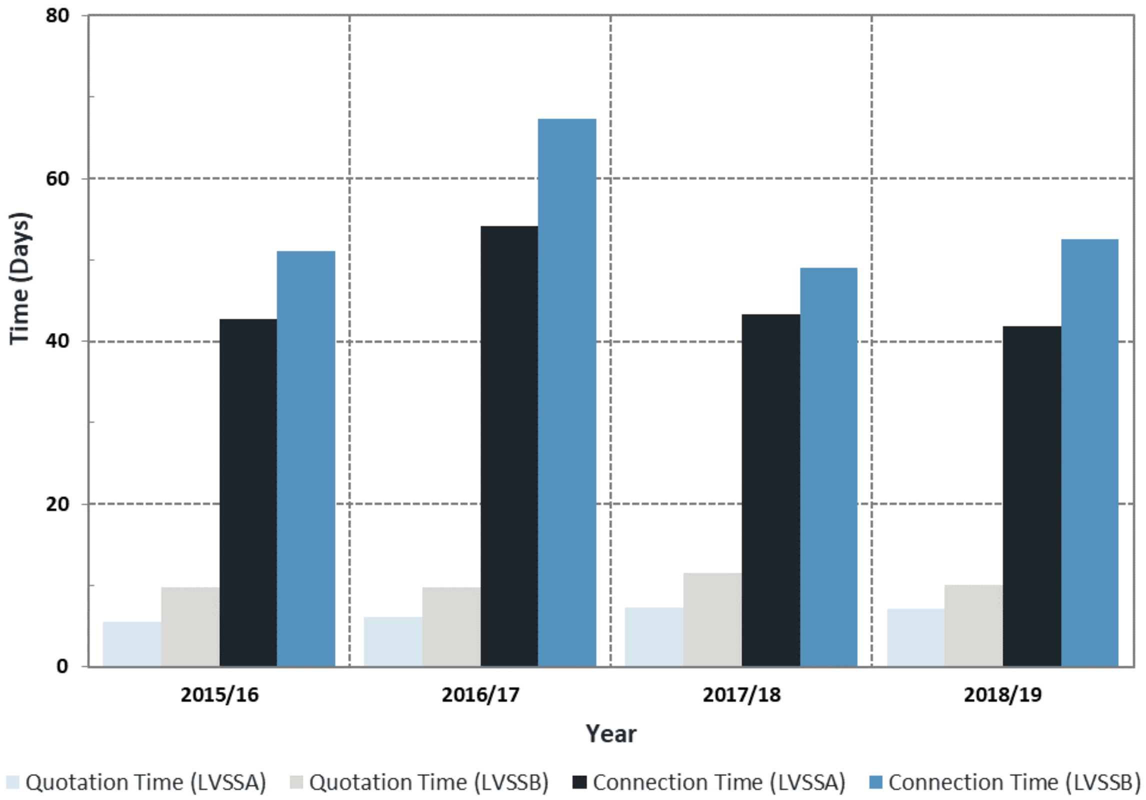


As new low carbon technology will be connected to the site, it is important to know how long it takes the EPN to provide a quote for a single connection as well as how long it takes for the connections to be completed.

Connection customers are categorised into two main groups, LVSSA and LVSSB. LVSSA are customers that are looking to make single domestic connections which require no work on the mains at low voltage whilst LVSSB are customers that are looking to make two to four domestic connections or one-off commercial connections at low voltage which will require no reinforcement work.

Figure B-6 shows the different connection and quotation times for each of the customer groups. According to UKPN's annual report, in 2018/2019 the average time in days the licence area took to provide a quote for an LVSSA connection was 7.1. This value exceeds Ofgem's limit of 8.2 days by 13%. These LVSSA connections were then seen to be completed in an average of 41.9 days which is 0.5% better than Ofgem's target.

Figure B-6 - EPN's Connection and Quotation Times



Appendix C

ELECTRICITY NETWORK INFRASTRUCTURE

The Burwell Grid Supply Point (GSP) is the part of the EPN's high voltage (HV) and extra high voltage (EHV) network supplying the site. The GSP is a 400/132kV National Grid substation located on the eastern edge of Cambridgeshire and contains 3 x 240 MVA supergrid transformers. Burwell GSP supplies 132/33kV and 132/11kV grid substations located on the northern and eastern borders of Cambridge, which then supply 33/11kV Primary substations throughout Cambridgeshire and the city of Cambridge. Figure C-1 provides an overview of the Burwell GSP network.

Figure C-1 - Burwell Grid Supply Point Network

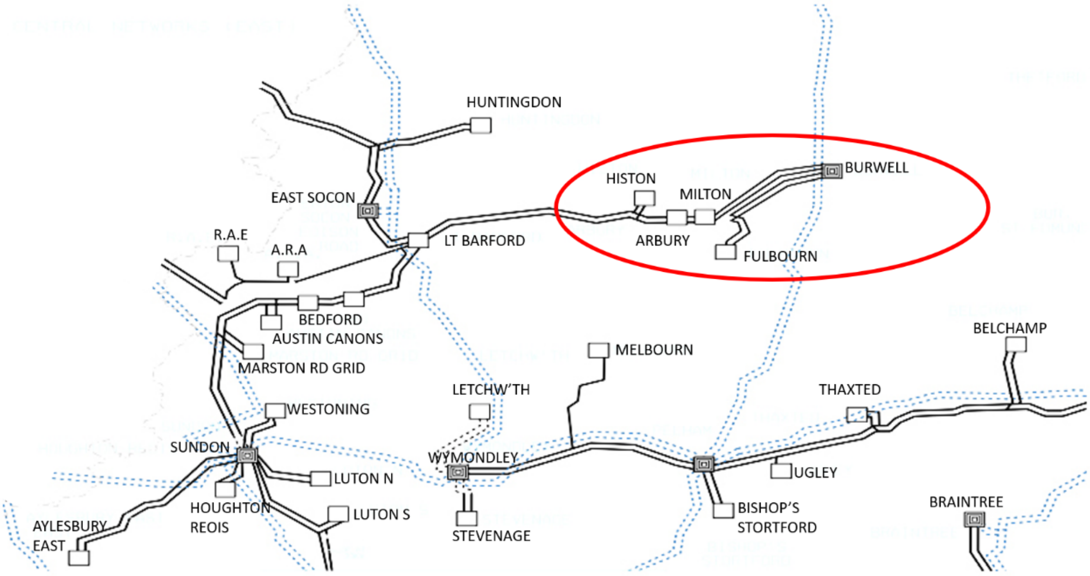
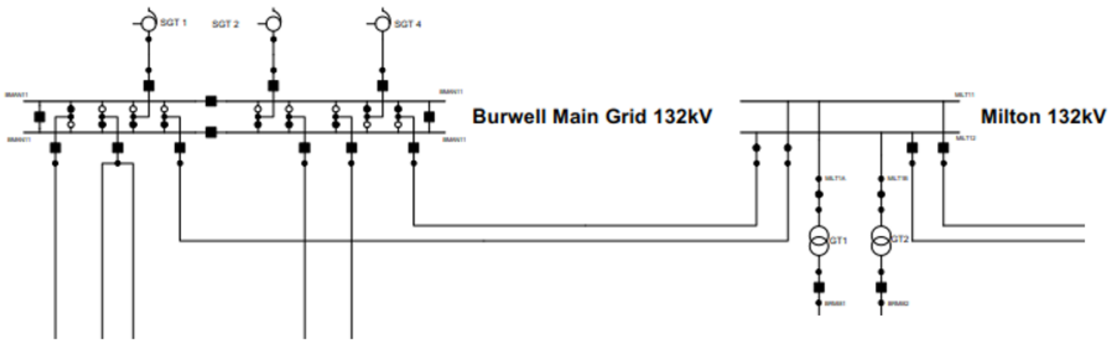
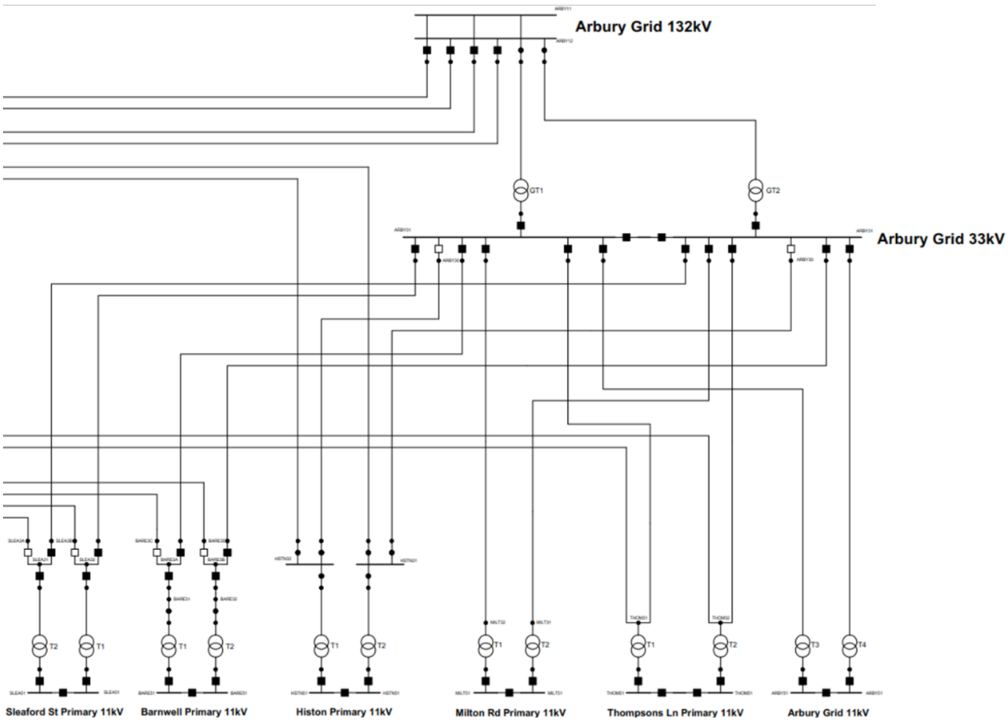


Figure C-2 - Burwell 400/132kV GSP connection to Milton 132kV Grid



The Burwell 400/132 kV GSP directly supplies the Milton 132 kV Grid which, in turn, is directly connected to the Arbury Grid Bulk Supply point (BSP) 132/33 kV substation. Arbury Grid BSP 132/33 kV substation supplies various primary substations in and around the NEC site, thus it would be focused on. The Arbury Grid BSP substation has 2 x 117 MVA transformers with a firm capacity of 109.7 MW and a maximum load of 71 MW. The firm demand headroom is 38.7 MW which is 35% of its existing capacity. The single line diagram of the Arbury Grid BSP is displayed in Figure C-3 ('Arbury Grid 132kV '/ 'Arbury Grid 33kV')

Figure C-3 - Arbury Grid Network



The primary substations supplied by Arbury Grid include; Milton Road Primary (33/11 kV), Sleaford Street (33/11 kV), Thompsons Lane (33/11 kV), Histon (33/11 kV) and Barnwell (33/11 kV) as shown above. The substation that directly supplies the site is Milton Road Primary (33/11 kV). The substations are listed in below along with their respective present firm capacities, loading, generation and headroom capacities.[29]

Table C-1 - Primary Substation Capacity and Headroom

Name	Voltage (kV)	Season	Firm Capacity (MW)	Maximum Load (MW)	Estimated Available Headroom (MW)	Transformer rating (MVA)	Generation (MW)
Milton Road	33/11	Winter	22.1	15.4	6.70	46.0	1.08
Milton Road	33/11	Summer	15.9	13.1	2.80	34.6	1.08
Sleaford Street	33/11	Winter	35.7	18.2	17.5	76.0	N/A
Sleaford Street	33/11	Summer	27.4	16.4	11.0	57.0	N/A
Thompsons Lane	33/11	Winter	36.6	15.3	21.3	80.0	N/A
Thompsons Lane	33/11	Summer	24.7	12.8	12.0	51.4	N/A
Histon	33/11	Winter	22.1	10.3	11.8	46.0	84.2
Histon	33/11	Summer	15.9	7.67	8.23	17.3	84.2

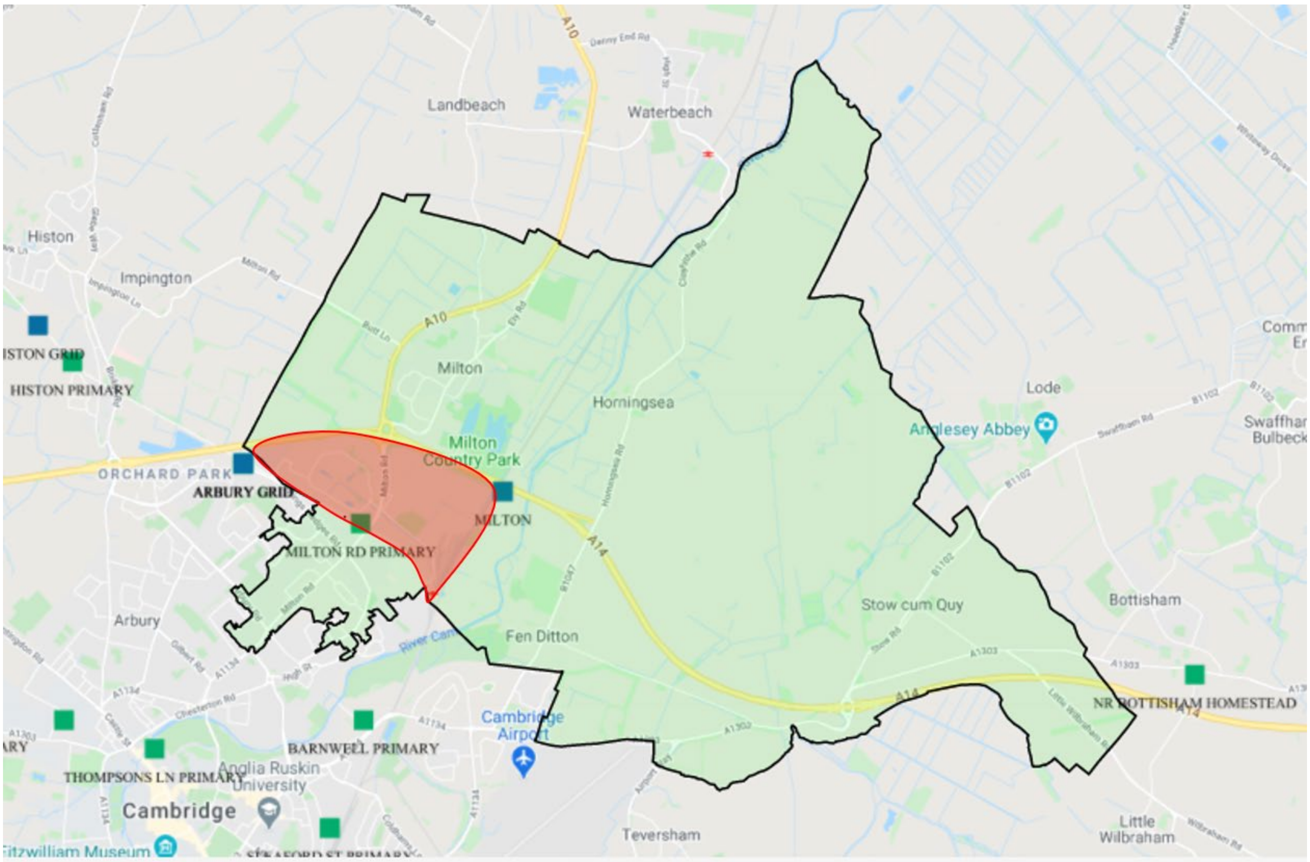
[29] https://www.ukpowernetworks.co.uk/internet/en/about-us/regulatory-information/ (accessed 10/10/2020)

Barnwell	33/11	Winter	18.7	11.1	7.61	34.6	N/A
Barnwell	33/11	Summer	14.4	7.70	6.70	30	N/A

Table C-1 shows the current as is status of the substations around the NEC site which supply domestic and non-domestic customers. This shows the voltage level customers will connect at (i.e. 11kV), the firm capacity and current maximum demand at each substation during the summer and winter months. The available capacity for connection at each of the substations is shown in the Estimated Headroom column. This is derived from the difference between firm capacity and maximum load and gives an indication if additional capacity will be required for connection.

Milton Road Primary 33/11 kV substation has 2 transformers with a combined transformer rating of 46MVA and a firm capacity of 22.1MW during the winter period. The maximum demand at the substation in winter is 15.4 MW, leaving an additional 6.70MW of available capacity. During the summer period, Milton Road has a combined transformer rating of 34MVA with a firm capacity of 15.9 MW. With a peak demand of 13.1MW during this period, a capacity of 2.8 MW is available.

Figure C-4 - Areas supplied by Milton Road Primary substation

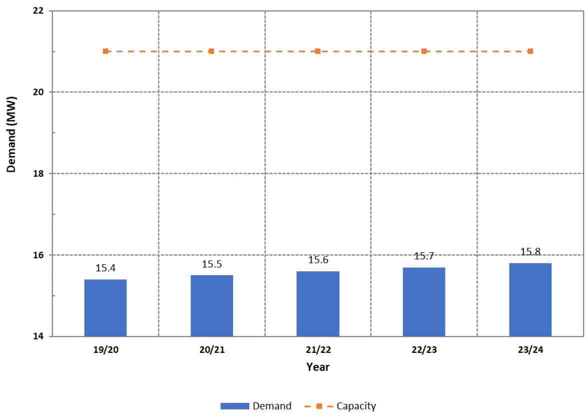


The area highlighted in red in Figure C-4 represents the location for the NEC site whilst the area highlighted in green represent the whole region supplied by Milton Road Primary. For the purpose of this report, no special consideration has been given to prospective projects that could connect to the substation. The forecasted load values used were those made available to the general public by UKPN and these only cover projections for the next 5 years.

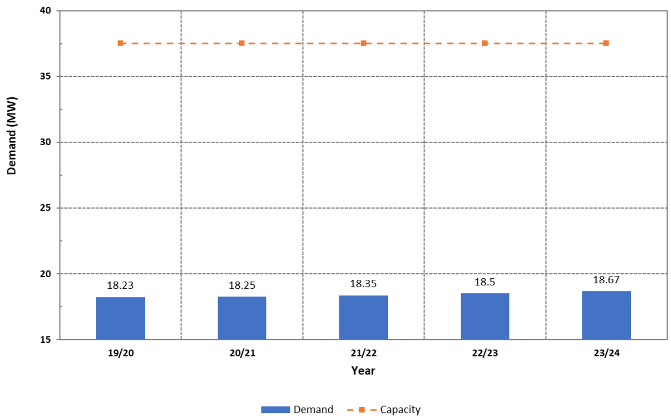
Long Term Development Plan (LTDS)

The Long Tern Development Statement (LTDS) supplied by UKPN provides network data that is used carry out forecasted feasibility studies and inform on development proposals. To understand the future state of the primary substations, capacity versus demand was plotted.

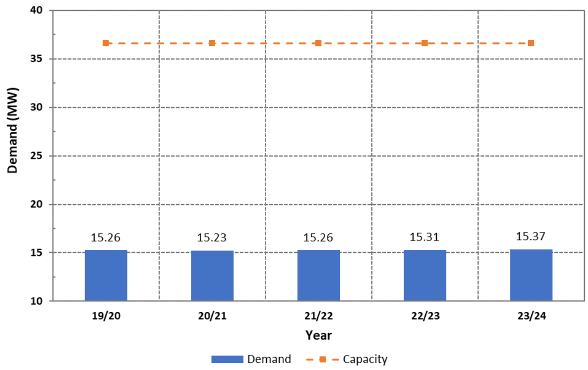
Figure C-5 - Maximum Demand Growth by Substation over 5 Year Period (Winter rating)



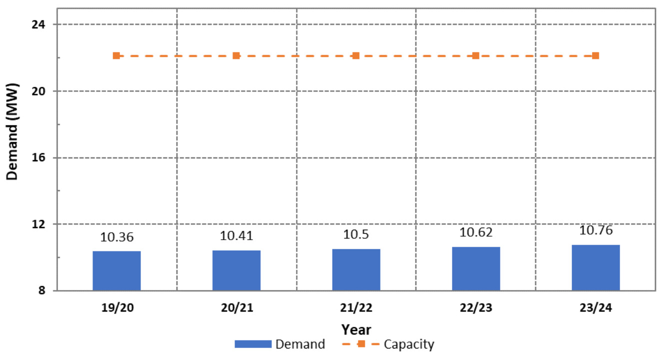
(a) Milton Road



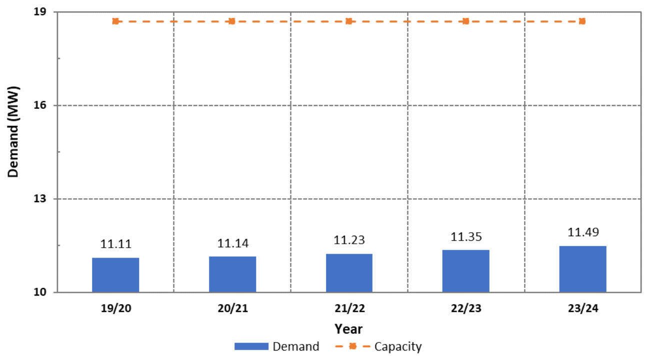
(b) Sleaford Street



(c) Thompsons Lane



(d) Histon



(e) Barnwell

From Figure C-5, it is observed that all substations experienced a slight growth in demand over the 5-year period. From Year 1 to Year 5, Sleaford Street saw the highest increase in demand of 0.44MW. Milton Road and Histon closely followed, each increasing by 0.40MW to 15.8 MW and 10.79 MW respectively across the same period. Also, in the summer period, Milton road saw an increase of 0.3MW to 13.4MW from Year 1 to Year 5. Additionally, Barnwell's demand increased by 0.38 MW to 11.49MW. Thompson Lane had the smallest increase (0.11 MW) to 15.37MW. Therefore, across the 5-year period the substations have enough capacity to deal with the growth in demand. Although Milton Road primary is the substation serving the NEC site, it is still important to gain an understanding on the current state of the substations in the region.

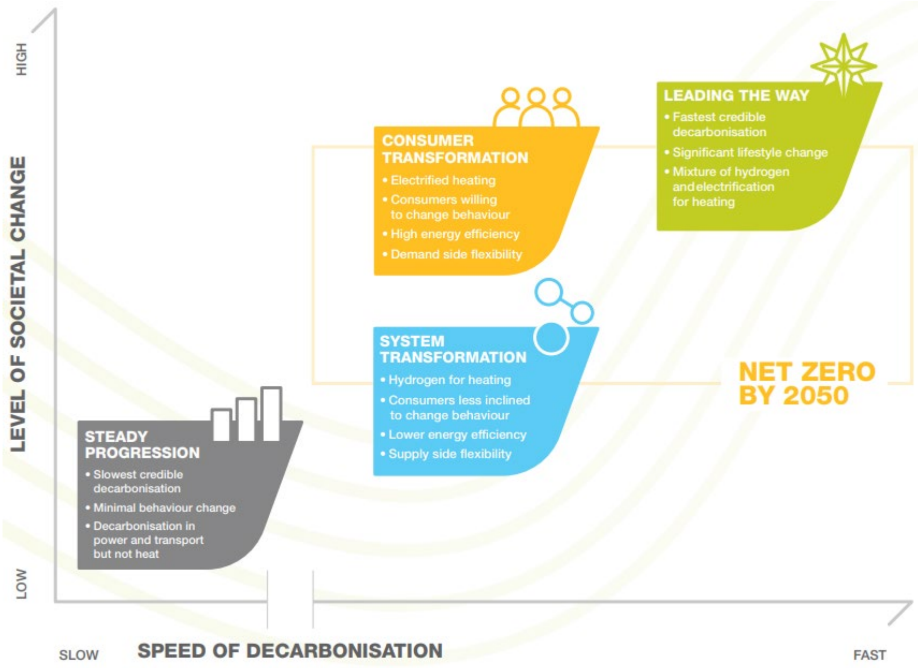
Future Energy Scenarios (FES)

The Future Energy Scenarios (FES) are designed to illustrate energy futures with different levels of decentralisation, decarbonisation, and digitalisation of energy. This is important as it helps visualise a greener future as the UK moves towards its 2050 net zero target. The scenarios are constructed from a series of key drivers, which are thought to have significant impacts on energy demand and supply across the domestic and non-domestic sectors. FES scenarios aid in providing the network provider and its stakeholders an understanding as to how electricity demand and generation on a local and national level will change in the future so as to:

- Inform urgent investment needed in energy infrastructure,
- Support energy policy decisions, and
- Investigate the impacts of changes in how energy is consumed every day till 2050.

Although UKPN provide its own Distribution Future Energy Scenarios (DFES), it does not provide suitable data for demand and generation thus, the analysis in this section was carried out using the FES 2020 data values provided by National Grid. [30]

Figure C-6 - Future Energy Scenarios



National Grid have defined 4 distinct scenarios that have net zero at the core and explore how the level of social change and speed of decarbonisation could lead to various possible routes as shown in Figure C-6 and doesn't take into consideration large scale developments to the order of the NEC site. The scenarios include; steady progression (SP), consumer transformation (CT), system transformation (ST) and lead the way (LW).

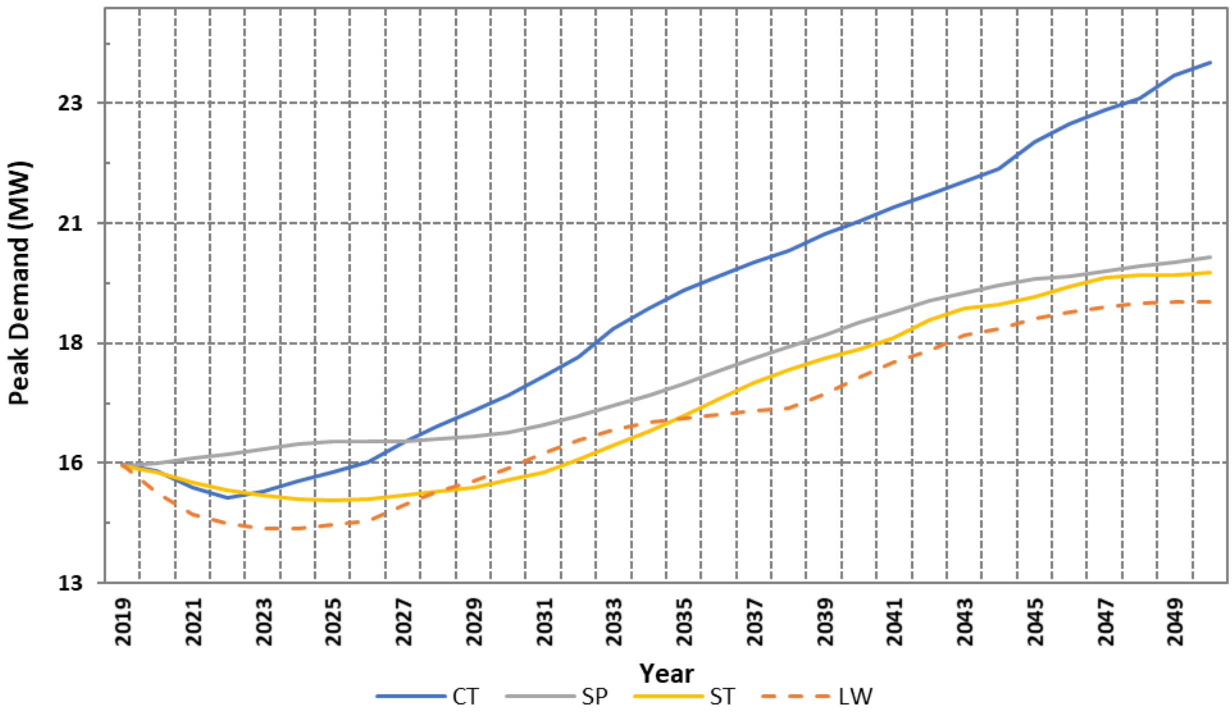
[30] https://www.nationalgrideso.com/future-energy/future-energy-scenarios/fes-2020-documents

Electricity Peak Demand

Here, demand refers to all electricity usage from both the domestic and non-domestic sectors including electrical heating & cooling as well as low carbon technologies. In recent times, smart technologies have been deployed in the grid to even out demand peaks. Examples include utilising battery storage solutions and discharging power from electric vehicles back to the grid, etc. As the nation moves towards net zero, there would be further development and deployment of such technologies.

Figure C-7 shows the evolution of electrical demand at Milton road primary under Nation Grid's FES scenarios. The figures used in the analysis where obtained using a demand coefficient of 0.035 which is a ratio of the current electrical demand at Milton Road Primary and Burwell 400/132 kV GSP. This was done to provide a high-level view of the peak demand over the next 30 years at Milton Road Primary and provides a magnitude of scale of what is to be expected at the substation.

Figure C-7 - Electricity Peak Demand of Milton Road Primary under FES scenarios



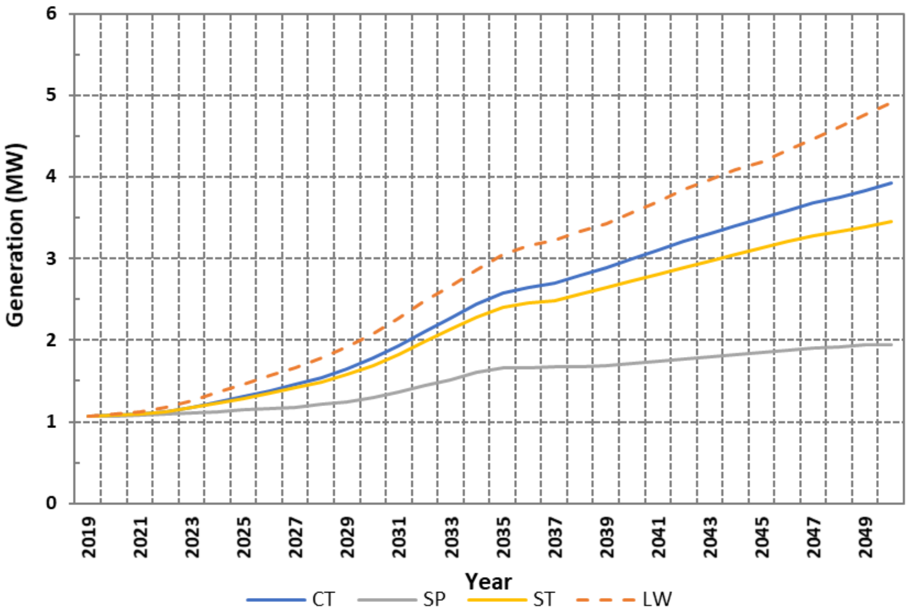
It can be observed from Figure C-7 that Milton road primary experiences the highest growth in peak demand of 8.3MW from 15.5MW over the 30-year period under the consumer transformation (CT) scenario. The steady progression (SP) and system transformation (ST) scenarios seem to yield similar peak demands at 2050 with 19.8MW and 19.5MW respectively. Leaving the most effective scenario at managing peak demand to be leading the way (LW) as it reaches 18.9MW at net zero. With the current firm capacity at Milton Road Primary being 22.1MW, the capacity at the substation is able to cope with the additional demand in all 4 scenarios.

Energy Generation

This forecasts the implementation various generation technologies in the grid. These include; non-renewable CHP, micro CHP, renewable engines (biogas, sewage gas, landfill gas), fuel cells, biomass & energy crops (including CHP), solar generation (large and small) and onshore wind.

In order to obtain the generation capacity forecasts for Milton Road Primary, a generation coefficient of 0.0017 was applied to the generation capacity expected at Burwell 400/132 kV GSP over the 30-year period under all FES scenarios and is shown in Figure C-8.

Figure C-8 - Generation Capacity at Milton Road Primary under FES scenarios



As the ‘leading the way’ (LW) scenario has the fastest uptake of new technologies out of all the other scenarios, this is the reason it has the highest generation capacity at 2050 with 4.91MW from 1.08MW. The steady progression (SP) scenario’s generation capacity increases by just 0.87MW over the 30-year period making it the lowest projection outcome. This is because the scenario considers the slowest rate of technology deployment onto the grid. Under the consumer transformation (CT) and system transformation (ST) scenarios, the generation capacity increases similarly reaching 3.9MW and 3.5MW respectively at 2050.

Appendix D

GRID REINFORCEMENT OPTIONEERING

OPTION OVERVIEW

The table below summarises the options/solutions for increasing network capacity and improving network efficiency.

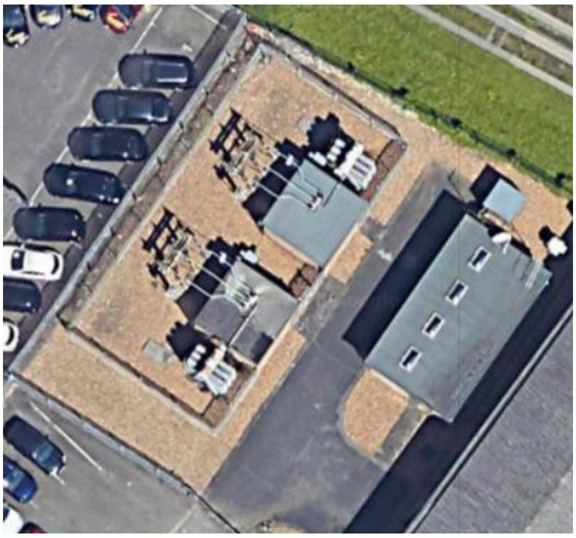
Table D-1 – Options Overview

	Option	Details
1	UKPN delivers reinforcement work required at Milton Road primary substation funded by applicant.	Reinforcement costs of the 11kV network is taken on by the applicant after accepting the formal offer from UKPN. The costs of works carried out at 33kV are also covered by the applicants whilst the costs at 132 kV are fully met by the DNO. Reinforcement works usually take 2-6 years to be completing depending on the level of works required. The applicant also has the opportunity to recoup some of the initial investment if another party aims on using the network in the future.
2	Using Independent Distribution Network Operator (IDNO) to recoup initial investment.	In this case, the IDNO would purchase the equipment used to reinforce Milton Road Primary from the applicant. This leads to the IDNO owning and operating this network and carrying out any future maintenance activities needed.
3	Deploying battery solutions to boost network capacity.	UKPN carries out engineering assessments on the grid to identify where battery solutions can be deployed to defer the need for reinforcement works and support network constraint management. This solution focuses more on improving the efficiency of the network rather than adding additional demand. Deploying battery solutions onto the grid provides the opportunity to provide extra revenue streams by offering balancing services to other parties in the market, but grid reinforcement would still be required.
4	Smart Grid with Local Authority Energy Service Company (ESCO) as the utility provider.	This option involves an ESCO taking responsibility for all aspects of the utility network which includes battery storage, energy generation. This option gives the opportunity for each dwelling to have solar PV and a battery serving as its own microgrid. As the NEC site is looking to have low carbon technologies such as solar PVs, heat pumps and battery solutions, this route gives the local council the prospects of setting achievable renewable and CO_2 reduction targets for the site.

OPTION 1: UKPN DELIVERS REINFORCEMENT WORK REQUIRED AT MILTON ROAD PRIMARY SUBSTATION FUNDED BY APPLICANT.

The current regulatory framework stipulates that National Grid funds reinforcement works on the 400kV network and the DNO of the region covers the work at the 132kV network. Reinforcement at 33kV are split between the DNO and the applicant whilst at 11kV, the applicant covers the cost in full after making formal applications. Although in this option, the applicant fully covers the costs at 33kV as the reinforcements are triggered by the needs of the applicant as opposed to the needs of the DNO. Under the second comer regulations, the applicant has the opportunity to recoup part of the initial investments in the first 5 years if under the ECCR (Electricity Connection Charges Regulations) of 2002 or in the first 10 years if under the ECCR of 2017 [31].

Figure D-1 - Aerial View of Milton Road Primary Substation



This option involves upgrading the Milton Road primary substation to provide additional capacity to accommodate the NEC site. Figure D-1 shows the current aerial view of the substation from which the substation housing and 2 transformers can be seen. The transformers have a combined rating of 46MVA which provides a firm capacity of 22.1MW. With a peak demand of 15.4MW, the available headroom at the substation is 6.7 MW – which is insufficient to cope with the additional 19.7MW the NEC site is projected to require. To accommodate the extra demand at the site and adhere to the N-1 security of supply requirement, a new 33/11kV 24MVA transformer has to be installed. Currently, the Arbury Grid BSP 132/33kV has the capacity to take on the additional load although this is not guaranteed until a formal connection application is made. If reinforcement works at Arbury BSP are needed at the time the application is made, the costs will be apportioned between UKPN and the applicant as both parties are benefiting from it.

At present, the substation site doesn't have enough ground space to contain a new transformer and this proves to be a limitation. This limitation can be mitigated in two ways, detailed below.

[31] https://www.ukpowernetworks.co.uk/internet/en/our-services/documents/Electricity_Connection_Charges_Regulations_October2014.pdf

Option 1a: Acquisition of land next to Milton Road Primary Substation

Figure D-2 - Land Option Next to Milton Road Primary

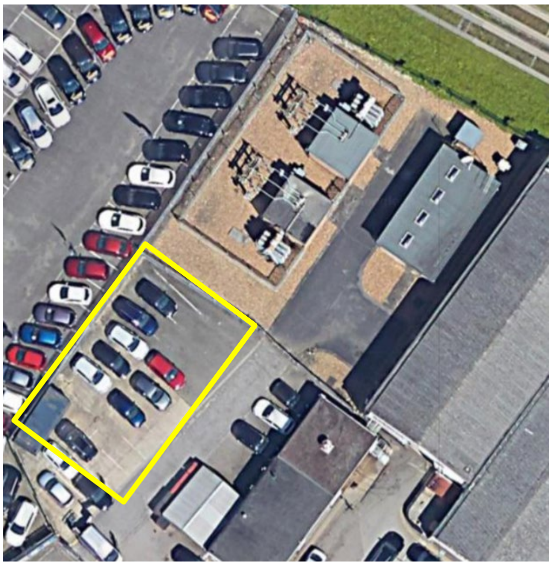


Figure D-3 - Distance between Arbury Grid and Milton Road Primary

In this option, the land directly beside the site, (highlighted in yellow in Figure D-2) will be acquired. With the approximate price of a piece of land per hectare in Central Cambridge being £6,250,000[32] and the estimate size of the land beside the substation being 390 m^2, the price of acquiring the land would be about £243,750. An additional 11kV switchboard will be installed in the current existing substation housing to feed the site at the 11kV voltage level. A 33kV cable of approximately 1.23km in length would be laid in a similar way through the course way (Figure D-3), to connect the new transformer to the Arbury Grid Bulk Supply point (BSP) 132/33 kV substation.

An indication of the high-level costs for this option are listed in Table D-2 – High-level Costing for Option 1A.

[32] https://www.gov.uk/government/collections/land-value-estimates

Table D-2 – High-level Costing for Option 1A

Equipment	Cost (£)
33/11kV 24MVA Transformer	323,000
11kV Switchboard	27,000
33kV Panel	67,000
33kV Cable	322,000
Civil Works	152,000
Land Acquisition	244,000
Protection & Control	22,000
Transportation	38,000
Erection and Commissioning	190,000
Total Costs	**£1,385,000**

*Prices listed above may differ when a formal connection application is made to the DNO. These costs provided in this report are to serve as a guide for what is to be expected.

Option 1b: Acquisition of land in close proximity to Milton Road Primary substation

Figure D-4 - Land Option Opposite Milton Road Primary

This option involves procuring a piece of land within close proximity to the substation. An example of this is shown in Figure D-4 with the substation highlighted in red and a potential site highlighted in yellow.

In this option, a transformer will be situated in close proximity to Milton Road Primary. An 11kV switchboard will be installed and housed, then this transformer will be linked to Milton Road Primary by an 11kV cable. The costs associated with this option are similar to those found in the previous section but vary due to additional equipment needed. The price of the land and cables are dependent on the plot acquired and the distance of it from the substation. Prices provided in Table D-3 were costed based on the parcel of land highlighted in yellow in the above figure.

Table D-3 – High-level Costing for Option 1B

Equipment	Cost (£)
33/11kV 24MVA Transformer	323,000
11kV Switchboard	27,000
11 kV cable	17,000
33kV Panel	67,000
33kV Cable	322,000
Civil Works	156,000
Land Acquisition	757,000
Protection & Control	22,000
Transportation	39,000
Erection and Commissioning	194,000
Total Costs	**£1,924,000**

OPTION 2: USING INDEPENDENT DISTRIBUTION NETWORK OPERATOR (IDNO) TO RECOUP INITIAL INVESTMENT.

IDNOs are private developers that have the ability to design, install, own and operate distribution networks located within areas covered by the DNOs. IDNO networks are either directly connected to the DNO network or indirectly via another IDNOs network.

IDNOs are regulated in the same way DNOs are, although their operating licence doesn't have all the conditions of the DNO licence. The Office of Gas and Electricity Markets (Ofgem) regulates the amounts these IDNOs can charge their customers for using their networks through 'Relative Price Control'. This ensures that the IDNOs are charging their customers at a price broadly consistent with the DNO equivalent charge.

In this option, a new substation similar to Milton Road Primary would be built. Here, the client would utilise the services of an Independent Connection Provider (ICP) to carry out the works needed. The ICP would liaise with IDNO to build this substation to their design requirements and then purchase the assets required.

For this new substation, to adhere with the N-1 requirements for security of supply, 2 X 33/11kV 24 MVA transformers would be needed, 2 X 33kV cables would connect the transformers to Arbury Grid BSP and a new piece of land of similar size to the Milton Substation would be purchased as well as 33kV switchgear and 11kV switchboard.

Upon completion of the works, the IDNO then buys back the assets at market rate which allows the client to recoup part of the initial investment. After the IDNO purchases the assets, the IDNO would then own and operate this part of the network as well as carry out any future maintenance and repair activities. Costs paid to the ICP for the construction of the substation are not recovered.

Table D-4 provides the costs associated with this option. It should be noted that these costs take into consideration of the construction of the new substation alone and does not consider any other works required to connect to Arbury Grid BSP.

Table D-4 – High-level Costing for Option 2

Equipment	Cost (£)
33/11kV 24MVA Transformers	645,000
11kV Switchboard	27,000
33kV Panel	67,000
33kV Cables	644,000
Civil Works	281,000
Land Acquisition	484,000
Protection & Control	22,000
Transportation	71,000
Erection and Commissioning	351,000
Total Costs	**£2,592,000**

OPTION 3: DEPLOYING BATTERY SOLUTIONS TO BOOST NETWORK CAPACITY.

Reinforcing the distribution network is very essential as it ensures it is operating within its operating constraints as demand and generation on the network increases, due to the entrant of low carbon devices such as electric vehicles and electric heating. Conventional network reinforcement is now being replaced with the deployment of energy storage in the distribution network.

This option involves batteries being deployed to support grid efficiencies which in turn, will free up additional capacity. The batteries will be charged at night where electricity is cheaper, load is low and the grid is not constrained and then, during the daytime when the grid is more constrained, demand can be supplemented by discharging the battery. Using this technology aids to achieve Net Zero as electricity used during the night to charge the battery is mostly from renewable sources.

Storage can provide support to the network in the following ways:

- Power Flow Management: Battery storage helps mitigate peaks in demand, level the load, balance demand across phases to minimise current flowing through neutral cables and also, reduce reverse power flow.
- Ancillary services for load balancing and grid stability
- Voltage: Storage has the ability to both inject and absorb reactive power in the network to help solve under-voltage, over-voltage, voltage unbalance, voltage quality issues, provide power factor correction, reduce the need to constrain Distributed generation, etc.
- As losses in a distribution network are a function of current flowing through cable resistance, the use of storage helps reduce technical losses.

Examples of storage technologies that are available in the market or that are currently being developed include:

- Lithium-Ion batteries
- Lead Acid batteries
- Flywheels
- Compressed Air Energy Storage (CAES)
- Hydrogen
- Thermal storage
- Pumped storage
- Flow batteries

For the purpose of this project, Lithium-ion batteries are the candidate technologies due to market deployment, technology maturity and local site conditions.

DNOs in the UK are prohibited from owning or operating energy storage solutions due to market distortions that could result from such activity. DNO ownership could obstruct a competitive market for network flexibility services thus, a third party will be used to provide this service. The third party will be in charge of building, owning and operating the asset and monetising additional revenue streams.

The NEC site is projected to have a total demand of about 19.7MW and with the available headroom at Milton Road Primary being 6.7MW, this means that there is a deficit of around 13MW. The available capacity in the off-peak periods is far below the capacity that is required to charge an energy storage system that could subsequently meet the peak load requirements. Therefore, any energy storage solutions would only be able to compliment grid reinforcement and not replace the need for it.

Battery Case Study

The Smarter Network Storage (SNS) project which is regarded to be Europe's biggest storage exists in the UKPN network. The project is located at the Woodman Close substation and serves the customers in Leighton Buzzard located in Bedfordshire. The 6MW/10MWh battery consists of 50,000 lithium-ion batteries that store enough power to serve 6,000 homes for 1.5 hours during peak times. During low or average electricity demand times, the battery is able to power 1,100 UK homes for a whole day or up to 27,000 homes for an hour.

OPTION 4: LOCAL AUTHORITY CREATING ENERGY SERVICE COMPANY (ESCO) AS THE UTILITY PROVIDER.

In recent years, the interest in the provision of energy services to achieve environmental and energy goals has increased. The number of companies that provide energy services to final energy users including the supply and installations of energy efficient equipment have started to operate in the market. These companies are referred to as ESCos.

An ESCo is a business that provides a broad range of energy solutions including:

- Designing and implementing energy saving projects,
- Energy analysis and audits,
- Energy management and conservation,
- Retrofitting,
- Power generation,
- Infrastructure outsourcing, etc

An ESCo is different from traditional energy companies in that they have the ability to finance/ arrange financing for the project. ESCos guarantee energy savings and the provision of the same level of energy at a lower cost as well as guarantee performance of the service. A certain degree of risk is also taken on by the ESCo for the delivery of improved energy efficiency at a facility and have their payment based on the achievement if these energy efficiency improvements.

In this option, the local authority would set up an ESCo and become the utility provider. The ESCo would also negotiate all the utility packages in the same way a master residential developer would for a large residential development. This will enable the local authority to meet its own renewable energy generation, CO_2 reduction targets for the development and other goals set whilst generating a profit from services.

There are 3 different approaches to which the local authority can set up an ESCo. High level descriptions of the approaches are given in Table D-5.

Table D-5 – Approaches for Local Authority to run ESCo

	Option	Description
1	Local Authority operates alone	The local authority handles and delivers the full scope of energy services required to the customers in the area through a wholly owned company. This approach involves the local authority having total control as well as high returns with the ESCO model. All financial, operational and development risks associated with the ESCO would also be borne solely by the local authority.
2	Local Authority forms partnerships in joint ventures	The local authority sets up a wholly own company with the objective of working in joint ventures with other parties to deliver energy services for the area. This approach has moderate risk as forming partnerships with other parties allows shared control of developmental & operational activities and revenue.
3	Local Authority acts as a Coordinator	The local authority would act primarily as a coordinator for other third parties to deliver energy services for the area. The local authority

		could render services through providing concessions or by acting as an investor. This approach has the lowest risk on the local authority as it is fully dependent on the third party's ability to deliver the services required.

Table D-6 provides assessments of each approach against capital, return, control and overall risk.

Table D-6 – Assessment of Approaches

	Capital	Return	Control	Risk
Option 1	Higher Costs	Higher Return	More Control	Higher Risk
Option 2	Moderate Costs	Shared Returns	Shared Control	Moderate Risk
Option 3	Lower Costs	Lower Return	Less Control	Lower Risk

Before a preferred approach or a fusion of approaches is chosen, local authority interviews and stakeholder workshops have to take place so that the approach is tailored specifically to those stakeholders. The main stakeholder groups involved in the process are:

- Community Energy Social Enterprises
- Local Authority
- Landowners
- Social Housing Providers and
- Other Public Sector Organisations.

The activities that would occur in these workshops comprise of the following:

- Mapping out current and future stakeholder responsibilities,
- Reviewing scope of key energy services,
- Examine an indicative scale for project viability
- Reviewing case studies from other local authorities and
- Strength based analysis of governance options for the ESCO.

These interviews and workshops would help establish the key strengths and constraints of each stakeholder, which would then directly inform the approach to be considered.

Appendix E

EV CHARGEPOINT

Examples of various approaches to chargepoint procurement can be found below.[33]

Table E-1 – Summary of procurement approaches taken by local authorities

Approach or case study	Type of charging infrastructure	Chargepoint network ownership	Funding source for chargepoint units & installation	Responsibility for maintenance & repair	Revenue arrangements	Risk liabilities (i.e. unexpected costs)	Framework & contract length	Procurement complexity
ChargePlace Scotland	National network, slow and rapid chargepoints	'Host' – local authority or organisation (i.e. workplace)	Up to 100% government grant from Transport Scotland	Transport Scotland, on an ad hoc basis	Most chargepoints are free to use for a certain time period, 'host' pays for electricity	With Transport Scotland and local authorities	NA	List of approved installers available to 'hosts'
Most current procurement to date	Dependent on grant scheme	Local authority	75% Central government grant, 25% Local authority funds	Local authority (monthly service fee paid to contractor)	All to local authority	With the central & local government	Varies	Simplified supplier selection if use the ESPO or TMT2 Frameworks
Private sector match funding	Dependent on funding stream	Local authority	75% Central government grant, with 25% private sector investment	To be agreed between parties	To be agreed between parties	Shared between public and private sector	Varies	Coventry City Council used ESPO Framework with additional requirements
Central Southern Regional Framework	All types of chargepoint	Contracting local authority	Grant funded or private sector finance option, brokered by supplier	Chargepoint supplier	10% rebate to council on energy costs. 1% revenue to Hampshire City Council when	Site dependent, shared between parties	Framework: 2+2 years Contracts: up to 15 years	Initial investment by Hampshire County Council to set up, now streamlined call off process

[33] https://energysavingtrust.org.uk/wp-content/uploads/2020/10/Local-Authority-Guidance-Procuring-electric-vehicle-charging-infrastructure.pdf

					other organisations use framework			
Greater Manchester EV Network	Lot 1: GMEV infrastructure	Local authority	Central or local government funding	Contracted supplier	All revenue collected by GMEV	With central and local authority	Framework: 7+3+3 years	New framework but relatively straightforward as ‘operate & own’ approach, added social and innovation criteria
Greater Manchester EV Network	Lot 2: Supplier owner infrastructure	Supplier	Private sector investment	Chargepoint supplier	All to supplier, which pays a ‘landlord rent’ to GMEV	Transferred to supplier	Framework: 7+3+3 years	More significant investment in framework development and contract negotiations
GULCS London Concession Framework	On street chargepoints, up to 7kWh	Borough	75% Central government grant, 25% boroughs funds	Chargepoint supplier	Most to supplier, with a share to the borough	Transferred to supplier	Framework: 3+1 years Contracts: 10 years	Invested resources to set up framework but will reduce costs and assist many boroughs
Oxford City Council Concession Framework	On street chargepoints for residents – innovation trial	Local authority	Central government grant	Chargepoint supplier	Most to supplier, with a revenue share to the council, once chargepoint profitable.	Transferred to supplier	Contract: Leased to operators for 4 + 4 years	Significant officer time invested, drawing on learnings from other local authorities. Trial framework will provide the groundwork for city wide infrastructure roll out
Go Ultra Low Nottingham	Fast & rapid chargepoints,	NCC owns underground network	Supplier claims against central government	Supplier	Minimum guaranteed payment and a	Transferred to supplier	Framework: 10 years	Resource intensive to establish as innovative model but

Concession framework			grant, supplier will provide additional funds if required and additional rapid chargepoints		revenue share paid by supplier to local authority		Contracts: 5+5 years	lead to a successful, low risk infrastructure delivery
Low upfront cost models E.g. Mid Devon District Council & Instavolt, BP Chargemaster, Plug in Suffolk	Fast and rapid chargepoints	Supplier	Private sector investment	Supplier	All to the supplier.	The council may receive a rental income for the use of their land	Transferred to supplier	Dependent on contract, often long term Likely to be simpler than a regional or network wide procurement framework. Officer time will be needed to develop the tender documents and negotiate revenue share/legal arrangements

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