Site Viability Assessment

NOKE SOLAR FARM- LAND OFF B4027, MANOR FARM, NOKE, OXFORD, OX3 9TU

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1.0 INTRODUCTION

1.1 This report has been prepared by Green Nation Energy Limited to review and assess the viability of the proposed site with respect to site location, grid availability and suitability. The proposed site location is Land Off B4027, Manor Farm, Noke, Oxford, OX3 9TU. The location is within Cherwell District Council.

1.2 This report describes the selection process that was completed to ensure the most suitable site was selected for a solar farm within the Cherwell District.

1.3 The UK has committed to achieving net zero emissions of CO_2 by 2050. A 68% reduction to emissions is required by 2030. A major element of the changes required to achieve that goal is a transition of the electricity network from generation largely based on fossil fuels such as coal and natural gas to renewable energy, in particular wind and solar. The UK is and will continue to be a leader in the development of renewable energy generation assets.

1.4 The transition from fossil fuel derived fuels includes the electrification of transport and space heating. Demand for electricity is set to exponentially increase throughout the transition period.

1.5 Cherwell District Council has declared a Climate Emergency.

1.6 The planning application is for a solar farm approximately 25MW in size, providing enough energy to power approximately 7,000 homes and save 12,000 tonnes of carbon dioxide each year.

2.0 STUDY AREA

2.1 The substantial growth of distributed generation assets over the last decade within the UK coupled with underinvestment in distribution network infrastructure has significantly constrained the development of renewable energy projects. The majority of remaining unused network capacity has been allocated. The identification of spare capacity within the Distribution Network Operator (DNO) network area drives the location of this and most other solar farms.

2.2 The county of Oxfordshire is supplied with electricity through networks owned by two DNOs: Western Power Distribution (WPD) in the northern part of the county, and Scottish and Southern Electricity Networks (SSEN) to the South.

2.3 The DNO networks include Low Voltage lines supplying residential and commercial premises, 11kV lines, 33kV lines and a few higher-voltage lines for trunk routes. Low Voltage lines are unsuitable for carrying power generated by anything bigger than a rooftop installation. The 11kV network has been used to connect a number of smaller solar farms, as the equipment required to do is more cost effective than for the 33kV network, and this helped smaller solar farms to be economically viable. Unfortunately, the 11kV network is essentially saturated now, and in the absence of subsidies for new solar farms, other factors make smaller farms less economic. The remaining scarce capacity available is on the more expensive 33kV network which means new solar farms have to be larger to ensure economic viability.

2.4 To ensure the solar farm is economically viable the development of this proposed size should if possible be within 1.5km of a suitable Point of Connection (POC).

2.5 Sections 3 and 4 provide detail of the alternative areas considered along with the various constraints and designations.

2.6 Through careful geographic information system mapping we were able to identify spare grid capacity within the Cherwell District Council geographical boundary.

2.7 The project development team engaged with Scottish and Southern Energy Networks (SSEN) through connection surgeries to discuss the grid capacity availability within this geographic area. Grid capacity is very limited within this area of the network. The development team identified available grid capacity on the 33kV feeder route between Bicester Primary Substation and Headington Primary Substation. This capacity defines the site area parameter.

Figure 1- Cherwell District Council Boundary map (NAREC Report- January 2020)

3.0 GRID CONNECTION CONSTRAINTS

3.1 NAREC Distributed Energy are specialist consultants on grid connections and grid network capacity. Green Nation appointed NAREC to review the Cherwell District Council geographical area to determine what available capacity exists on the grid and at what locations it would be feasible to connect to it.

3.2 NAREC produced a Network Availability Report (Appendix A). The report analysed the WPD and SSEN Substations that serve the Cherwell District Council geographical area. The report states there is only one cable route in the Cherwell District Council area capable of providing an 18 MVA connection. The cable route runs between Bicester Primary Substation to Headington Primary Substation. To ensure the project is commercially viable the project will have to be within 1.5km of an available Point of Connection (POC) to the cable route.

3.3 Due to upstream constraints and thermal limits Bicester Primary Substation is unable to accept additional export connections, due to upstream constraints and thermal limits. The Normal Open Point will be established at the Headington Primary Substation, so the supply is always provided by Headington Primary Substation. The circuit route is shown below in figure 2.

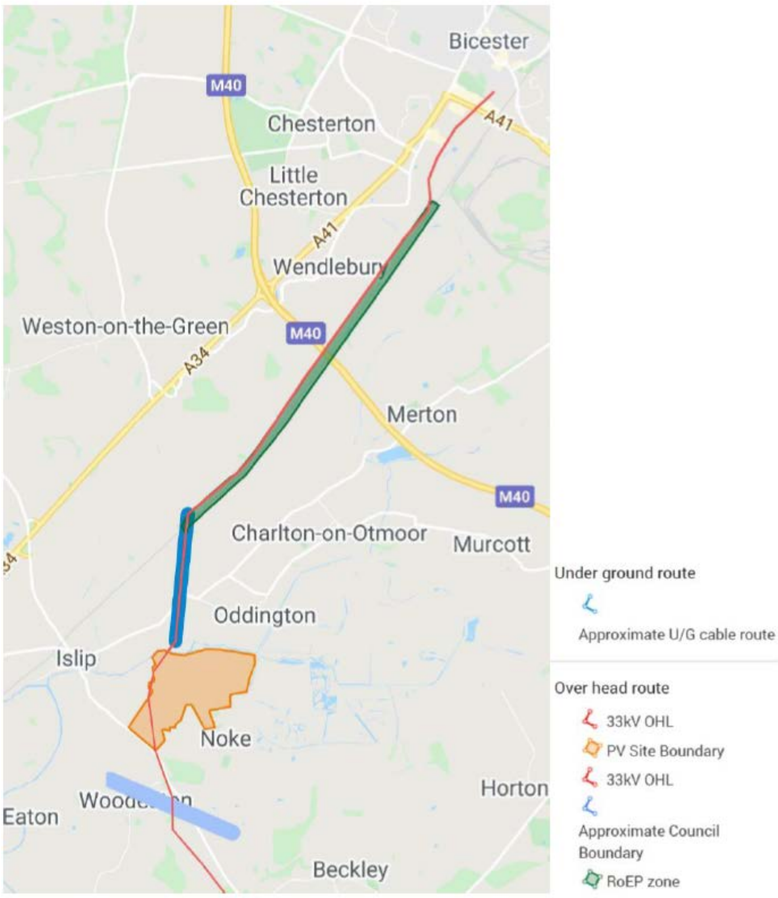

Figure 2- Circuit route (NAREC Report- January 2020)

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3.4 NAREC identified that due to the Rise of Earth Potential (RoEP) a significant proportion of the cable route (shown as green in figure 2) is unsuitable for a solar farm development. In the event of a high voltage Earth fault the soil resistivity would create a Rise of Earth potential outside of the legislated safe tolerances, this is compounded with the close proximity of the railway line and would therefore not be the most suitable location for a solar farm. The next section of the cable route, running south from the railway line is underground (shown as blue in figure 2), and not easily accessible. The route changes to an overhead cable at the River Ray boundary and south from there as far as the boundary of Cherwell District Council.

3.5 Pegasus Group the planning consultant were able to overlay the additional complex site constraints on to a single plan, 'Pegasus Connection Power Line Constraints Map' (Appendix B). The plan documents the other planning constraints such as existing and approved development sites, sites allocated for development within the Development Plan, ecological and heritage designations.

3.6 SSEN offered a Point of Connection (POC) at Pole 34, located in the Western field adjacent to the proposed site. Working on a 1.5km radius from the POC, sufficient land was available to support an 18 MVA solar farm.

3.7 The NAREC report concludes that the small area around Noke offers the only viable location for a new 18 MVA solar farm connection within the Cherwell District Council geographical area, feeding through to Headington Primary Substation.

3.8 In early 2022, we learned that a further significant constraint in the National Grid network means that the Noke project is one of only a few sites in Oxfordshire that will be able to connect to the electricity network before 2028. This constraint will affect the ability to meet interim targets for transition towards Net Zero, and further highlights the importance of the Noke project.

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4.0 DESIGNATIONS AND CONSTRAINTS

4.1 The grid capacity constraints set out above and, in the Appendix, significantly reduced the original geographical area under investigation for a potential solar farm site. Green Nation recognises the importance of a careful site selection process that includes proactive engagement with the local community and governing bodies to ensure a suitable project has a positive impact.

4.2 The Magic Maps extract at figure 3 demonstrates the key designations of the site area.

4.3 The proposed site area (outlined in red) is over 1.8km away from Otmoor Site of Special Scientific Interest (SSSI- shown in green below). It is situated within the outer impact risk zones of the SSSI. The site is 2.4km from Woodeaton SSSI site and 1.8km from Woodeaton Quarry SSSI (shown in red below). The RSPB Otmoor Nature Reserve is situated adjacent to Otmoor SSSI and extends to over 390 hectares. The green area is identified as favourable SSSI conditions from an ecological perspective, the red area is identified as unfavourable declining SSSI conditions from an ecological perspective. The proposed development avoids the proximity of SSSI sites, remaining outside the zones of influence, therefore would not have any adverse impacts on any of the designated sites in the surrounding area. Overall landscape proposals allow a significant net gain of 50.44%.

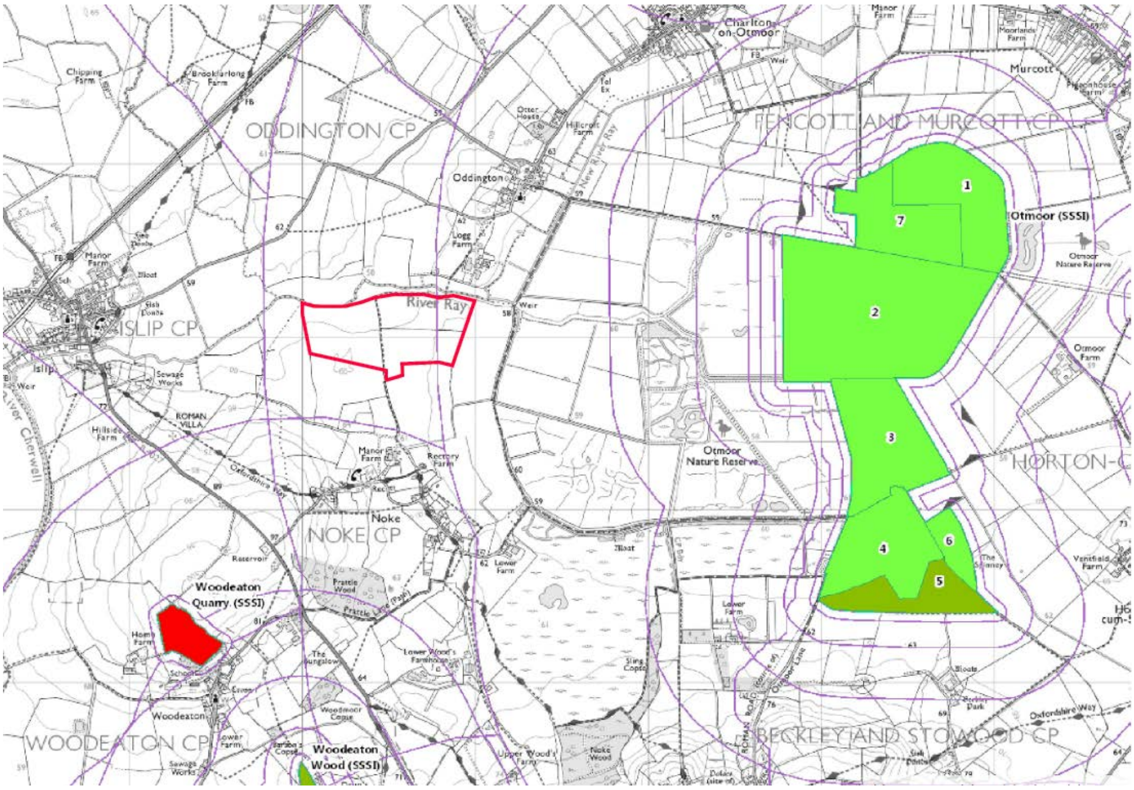

Figure 3- Magic Maps extract documenting land designations.

4.4 The site is located within close proximity to the RSPB Otmoor Nature Reserve. The location is instrumental to the project development, Green Nation recognises the symbiotic relationship between renewable energy and ecology and prides itself on proactive measures to strengthen this. As a direct result, this sets out the 'very special circumstances' case for the planning application.-The northern section of the eastern field will be removed from intensive arable production and developed as a key area for ecology. The island between the two rivers will also be utilised as a key area for ecology to significantly improve the biodiversity of the intensively farmed area. The periphery of the site will also be provided with ecological enhancements to improve biodiversity. Forthcoming guidelines call upon new developments to enhance Natural Capital by at least 10%. the development will result in the achievement of significant biodiversity net gains with an overall gain for habitats of 50.44% and a specific gain of 6.14% for hedgerow habitats, as set out in the submitted Ecological Appraisal.

4.5 Green Nation believes that solar farms have an important role to play not only in moving the country towards carbon neutrality but also in enhancing the biodiversity and overall environment of the locales within which they are sited. The proposed site has the greatest potential ecological influence on RSPB Otmoor Nature Reserve. Early engagement with the RSPB has allowed Green Nation to tailor the proposed ecological enhancements on and near the solar farm site to help species that are recognised to be in decline due to longstanding intensive agricultural processes. Enhancements are proposed within the application area that are designed to promote targeted species of birds.

Green Nation recognises that the North East corner of the development, adjacent to the River Ray would be the most valued habitat. Should RSPB Otmoor Nature Reserve wish to expand the boundary of the reserve in the future, Green Nation would be willing to hand over this area to support RSPB goals and objectives. Ultimately, the overriding strategy would take the biodiverse net gains made by the solar farm and continue to build and improve the habitat and surrounding area

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5.0 SITE AT MANOR FARM, NOKE

5.1 The total extent of the solar farm is 76 acres; solar panels will cover approximately 50% of the area. The solar farm will have biodiversity-enriched grass that supports sheep grazing. The periphery of the solar farm, the north section of the field to the east and the island will provide extensive biodiversity enhanced areas, resulting in the achievement of significant biodiversity net gains with an overall gain for habitats of 50.44% and a specific gain of 6.14% for hedgerow habitat. Increasing the ecological areas and improving the natural wildlife corridor along the River Ray will have an exponentially beneficial impact on the local area by extending the ecological impact zones.

When the landscaping and biodiversity areas are included, the total site area is 43.78 hectares (107.9 acres). The existing site access will be utilised to minimise impact of the development.

5.2 The site is located within 1.5km of a grid connection to export the electricity from the solar farm.

5.3 The Noke to Oddington footpath cuts the site into two halves separated by a wide avenue, and the Oxfordshire Way Public Right of Way (PRoW) is located over 550m from the proposed site but with some views over it.

5.4 The proposal includes a Landscape and Visual Impact assessment (LVIA) to ensure appropriate screening protects and minimises the impact of the views from these locations.

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6.0 COMMERCIAL VIABILITY

6.1 The abolition of key Government subsidy structures in 2015 caused the large-scale solar industry to come to a halt for several years. New solar farms were economically unviable at the time without the subsidy support. Once the remaining "grandfathered" sites had been completed, almost no new solar farms started construction until 2020.

6.2 The growth of the global solar industry over the last 6 years has enabled technological advances to continue. The increasing power output of solar photovoltaic modules, falls in solar panel prices and increased efficiencies in other aspects of the construction of solar farms have significantly reduced the cost per Watt to build a solar farm. The margins are exceptionally slim, but with strong investor backing, the solar power industry is in a position to make a vital contribution to the increase in renewable generation capacity required to support the UK Government's objective of Net Zero 2050.

6.3 The Noke Solar Farm proposal was reduced in scale to address the concerns raised during the planning Pre-Application process, and reduced further following the public consultation period. The development now only covers fewer than three of the five fields originally submitted to the Local Planning Authority (LPA) as part of the planning Pre-Application process, pursuant to pre-application ref. 20/00653/PREAPP. This significant reduction to the size of the scheme has challenged the economics of the project. The reduction in site size was achieved by a combination of using more powerful (and more expensive) solar panels, and by slightly decreasing the distances between panel rows, which has some impact on output per panel. As a result, the peak capacity of the site has remained at a sufficient level to ensure the project remains commercially viable while its physical footprint has reduced very significantly.

6.4 There are substantial fixed costs involved with the project:

i Redacted

6.5 Redacted

6.6 Redacted

6.7 Provided economic scale is achieved, Green Nation believes the solar farm will be viable throughout its planning life. As existing thermal power plants are retired, and with the increasing electrification of motor vehicles and domestic heating, the demand for electricity is projected to increase substantially over the coming years, which should counterbalance the dampening effect on prices over time of increased renewable energy capacity.

7.0 SUMMARY

7.1 The area covered by Cherwell District Council was analysed for potential available grid capacity. Due to the significant capacity constraints imposed upon the grid, only a small area of land within the District is suitable for a solar farm that would be commercially viable.

7.2 In summary, the proposed land at Manor Farm Noke is considered an appropriate location for the solar farm. The recommendations of ecologists' reports and Green Nation's engagement with RSPB enables the project to demonstrate the symbiotic relationship between renewable energy and biodiversity. The creation of the key ecological areas adjacent to the River Ray and removing the entire area from intensive agricultural production practices will result in the achievement of significant biodiversity net gains with an overall gain for habitats of 50.44% and a specific gain of 6.14% for hedgerow habitats, providing benefits for local protected species and providing a harmonious development with the nearby RSPB Otmoor Nature Reserve.

7.3 Public Consultation took place with the settlements surrounding the proposed site location, and the scale of the proposal was raised as a concern. All comments were reviewed and the scheme was revised to minimise the impact on the surrounding environment: the scheme was reduced to only two and a half fields from the original five fields proposed to the Local Planning Authority. A comprehensive review of the project economics ensures that even with the significant reduction in the scale of the project, it is able to reach the threshold of commercial viability to progress the development. However, any further reduction in scale would deter necessary investment into the project which would render the project unviable.

APPENDIX A- NAREC Network Availability Report

Network availability assessment, Noke, Oxfordshire.

Ken Pelton

January 2022

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Process

	Name	Date
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THIRD PARTY DATA

Narec Distributed Energy cannot be held responsible for the information & data provided by third parties. Any updates of the publicly available generation heat maps after the production of this report may render the information provided out of date.

Contents

1 Introduction

1.1 Narec DE

Narec Distributed Energy Ltd (NDE) is an organisation which carries out a wide range of work within the renewable and low carbon sector. Our work covers renewable energy, low carbon/carbon-negative housing, energy storage and grid connection. Within these areas we deliver consultancy, training and testing.

In terms of grid connection, our work ranges from assisting single bespoke homes with connections, up to full multi-MW solar farms, wind farms and battery parks. Our clients include small installation companies, local authorities and multinationals. We assist our clients every step of the way, from initial assessment and budget enquiry, through to detailed negotiations with DNOs/National Grid, and arrangement of ICP works.

1.2 Personnel

Our expertise is based around our former Distribution Network Operator (DNO) trained staff with over 57 years of UK grid experience between them. The team delivering this report are -

Bryan Dixon

Bryan heads up the grid connection work at NDE. He has over 37 years' experience in the electricity industry and is an expert within his area. Bryan works on the full grid connection of wind, solar and battery projects, from the initial grid feasibility all the way to full grid applications, negotiations with DNOs and appointment of ICP's and IDNO's.

Previous to NDE, he worked as a Senior Network Design Engineer at Northern Powergrid for several years, working on network studies, grid connections, system analysis, preparation of budget estimates, firm quotations, preparation of scheme drawings, customer visits, and liaising with wayleaves and construction engineers.

Prior to this, Bryan was a Senior Authorised Person / Project Manager for Balfour Beatty Power Services and Bethell Power Services and a Contract Manager for Bethell Power Services.

Prior to joining Bethell Power Services in 2002 Bryan was the Public Lighting Faults Manager for Northern Electric (now Northern Powergrid) an Overhead Linesman which followed on from him joining the N.E.E.B. (now Northern Powergrid) as an Overhead Line apprentice in 1982.

Matt Cocker

Matt has worked within the electrical industry for almost ten years and is highly experienced in the grid connection of EV chargers, energy storage and renewable energy systems.

Prior to working at Narec DE, Matt worked at Distribution Cable Jointing, where he undertook the design of connections of various energy generators, EV charging systems and loads for new developments. Within this role he also supplied Point of Connection applications and design approval paperwork to various DNOs. Other previous roles included working as a HV/LV Connections Design Engineer at Northern Powergrid, and before entering the energy industry he was the IT Network Infrastructure Manager at RAF Boulmer.

Tom Bradley

Tom has worked in the energy industry for over ten years, working on a range of generation technologies, including wind, wave, tidal, ground source, biomass, heat pumps, photovoltaics and solar thermal. He has also worked on projects involving various grid and storage technologies.

Tom has experience of analysis of large and complex datasets, using various pieces of scientific software, and designing bespoke applications. He has a strong knowledge of industry and speaks at relevant conferences. Tom is one of the co-owners and founders of Narec DE ltd.

2 Information sources

Narec Distributed Energy (NDE) have undertaken this study based on the publicly available generation heat map data provided by Western Power Distribution (WPD), UK Power Networks (UKPN) and Scottish & Southern Electricity (SSE). We have also used data provided in the Long Term Development Statements of all three DNOs and we have also referred to National Grid's (NGET) generation heat map to fully understand any upstream transmission constraints.

Note WPD's disclaimer regarding the accuracy of the information provided –

> *'We have developed the network capacity map to assist you with connections applications in constrained areas. The map gives a general illustration of availability constraints only and cannot be relied upon to assess the terms of connection for specific premises. Whilst we use reasonable endeavours to ensure that the network capacity map and related information is accurate, we do not warrant, and do not accept any responsibility or liability for, the accuracy or completeness of the content or for any loss which may arise from reliance on the network capacity map or related information'.*

SSE also have a similar but less specific disclaimer -

> *'Please note that distribution network constraints may be caused by a number of issues such as thermal, fault level, voltage constraints. Other constraints can be caused by physical space limitations within SSE licence areas or limitations imposed by the Transmission System Operator'.*

UKPN declare –

> *'The Distributed Generation map shows the approximate locations of our 33kV and 132kV overhead electricity network towers and poles. It also shows where our 11kV, 33kV and 132kV substations are approximately in the East of England and the South East. Please note the data provided is indicative only'.*

Note - the sources of information we have used for our report are constantly changing and are regularly updated. Therefore, the information we have included in this report is only guaranteed to be accurate on the day of publication.

3 Assessment area

The area that we have considered for the availability of a grid scale generation connection is the Cherwell District Council geographical boundary. The area the Council covers has a total landmass of 588.8 square kilometres (227.3 square miles). This area is supplied electrically via both WPD to the North, SSE to the South and is bordered by UKPN to the East. We have also considered all substations outside of this area which have a direct impact on substations within the outline boundary zone. This allows for a fair and accurate assessment of the total Cherwell District Council area. This area is shown within Figure 1.

Figure 1: Cherwell District Council Boundary map

4 Assessment criteria

All the sites have been assessed purely from an electrical generation connection point of view only. All constraints, issues and limitations have been considered and the available generation connection points shown. No consideration has been given to planning, areas of outstanding natural beauty (AONB) or areas of special scientific interest (SSSI).

4.1 System voltage selection

We have assessed every Primary Substation, Bulk Supply Point and Grid Supply Point that have an influence on the electrical grid in the Cherwell Council area. Local or Secondary Substations as they are known have been discounted as they operate at 11kV (11,000 volts) and as such they are inadequate to distribute the amount of export required which in this instance is 18MW (18.95MVA). The absolute maximum feeder capacity at 11kV is generally regarded to be 8MVA. This is only available if the maximum cable size is installed (300mm triplex) and a 400A circuit breaker is fitted at the Primary Substation. Obviously if the cable size is smaller (very common) or a 250A (or smaller) circuit breaker is installed then this capacity will be significantly reduced. It should also be noted that large scale generators normally have to be connected to a dedicated feeder and not 'teed in' to an existing one due to the requirements of intertripping (intertripping is where in the event of a fault the feeder trips at both the source end (generator) and the export point (Point of Connection) to ensure a safe network condition exists).

This means that the only viable connection voltage for this project is 33kV. This is because a 33kV feeder is generally capable of catering for 25MW or more with large cables and circuit breaker combinations. A 132kV or 400kV connection were also discounted as the cost of a connection is prohibitively expensive due to significantly higher plant, cable and connection works.

5 Constraints

Like the rest of the UK the WPD, UKPN and SSE distribution networks are under significant stress from the large number of renewable energy projects connected in their respective franchise areas. Due to the prevalence of high volts, fault level rating issues, thermal rating & current carrying capacity issues the distribution network has several heavily constrained areas. Many of the 132kV Grid and Bulk supply points and their associated primary substations have various restrictions to consider before a connection offer can be made for additional generation.

5.1 Constraints explained

There are many restriction or constraints which affect the connection of large-scale grid generation. The main areas which cause a constraint or lack of available connection capacity are as follows –

- **Fault level** – this is the amount of energy that would be released in the event of a short circuit. This can be either a single phase to earth (the most onerous scenario) or a three phase asymmetric fault to earth. The fault level limit is the upper rating of the connected equipment, with the usual 'weak link' being the switchgear. More generation = increased fault level.
- **High volts** – this is a situation on the distribution network where the amount of generation connected to the network causes the voltage to rise. If this exceeds statutory voltage levels then damage to consumers equipment may be caused and outages can occur. This is controlled by 'tap changers' at Primary Substations, however it is possible to run out of available tap settings and thus high voltages can occur.
- **Thermal rating** – this is where equipment (usually cables & conductors) heat up due to the amount of energy they are carrying. This can lead to failures and in the case of overhead lines it can also lead to low ground clearance issues due to excessive sag.
- **Current carrying capacity** – this is where the actual design limits of the equipment is exceeded which leads to accelerated wear and ultimately failure of a piece of plant or equipment.

- **Reverse powerflow capability** – certain grid transformers can often only cater for 50% of their normal working capacity as reverse powerflow. This is fairly common across the whole of the UK but it does reduce the amount of generation that may be connected.
- **Directional protection** – some Primary Substations have protection relays that only work in one direction and are therefore unsuitable to cater for any generation connections.

Generation projects which may have been accepted three to four years ago have now been fully constructed, commissioned and are now being energised; the amount of constraints on their respective distribution networks grows greater every day. Every update of the respective heat maps shows less & less opportunities to connect generation. This can literally vary from day to day, depending how often each DNO updates their respective heat maps. This is a very volatile and rapidly changing environment and it is only heading in one direction for the foreseeable future where eventually no further generation connections will be possible and the grid will be at saturation point.

To effectively manage the issues that they have on their respective networks and to maintain statutory voltage limits, WPD, UKPN and SSE have several different ways (some of them will operate concurrently with each other) to actively manage their networks. Some of these are listed below.

5.2 Powerfactor

In order to allow DNOs to contain voltage within acceptable limits at the National Electricity Transmission System (NETS) / Distribution System interface, the Customer must ensure that the generators (>=1MW) have the capability to operate between 0.95 leading and 0.95 lagging power factor. Customers will be advised of the target Power Factor within this range.

5.3 Disconnection

National Grid Electricity Transmission (NGET) has instructed that all UK DNOs shall maintain a facility such that under emergency conditions on the National Electricity Transmission System (NETS), DNO' shall have the ability to de-energise embedded generation (>=1MW) upon instruction from NGET.

5.4 South West Operational Tripping Scheme WPD area (SWOTS)

The Customer's generation will be included in the South West Operational Tripping Scheme (the SWOTS) required by National Grid Electricity Transmission (NGET). The SWOTS will automatically constrain the Customer's generation output to zero during N-3 outage conditions on the National Electricity Transmission System (NETS).

5.5 Active management

The Customer's generation will be included in the SGT Active Network Management Scheme (ANM). The ANM will automatically curtail the output of the Customer's generation in order to control power flow in reverse direction through the Supergrid Transformers (SGTs) at the Grid Supply Point.

5.6 Connect & Manage

The Customer's generation will be included in Connect & Manage arrangement to address transmission system constraints through NGET having better management, visibility and control of Distributed Energy Resources (DER).

6 Substations

The substations listed below are either in the Cherwell District Council geographic area or have a direct bearing on substations within the Cherwell District Council geographic area. The substations are listed with a note of any operational restrictions, constraints and limitations. Substations outside of the area and with no possible connection or influence on substations within the Cherwell District Council area have not been included in the list.

A GSP (Grid Supply Point) is where the DNO receives their incoming supply from National Grid (NGET). A BSP (Bulk Supply Point) is similar to a GSP but this is where the DNO supplies a number of its Primary Substations from. All other substations are Primary Substations which are where the DNO reduces their transmission voltage (usually 33kV down to 11kV) and then transmits this to Secondary or Local Distribution Substations. These Secondary or Local Substations then reduce the voltage to 230/400 volts.

6.1 WPD substations

There are ten WPD substations which have an influence on the Cherwell District Council geographical boundary.

- **East Claydon 132kV** – unable to accept additional demand or export connections due to the number of existing connections (both generation & demand).
- **Brackley 132kV BSP** – only able to accept a maximum of 5.1MVA of new connections or generation due to fault level issues.
- **Bloxham 66/11kV** - unable to accept additional demand or export connections due to the number of existing connections (both generation & demand).
- **Epwell 66/11kV** – only able to accept a maximum of 5MVA of new connections or generation due to fault level issues.
- **Thenford 33/11kV** - only able to accept a maximum of 6MVA of new connections or generation due to fault level issues.
- **Shipston 33/11kV** - only able to accept a maximum of 6.25MVA of new connections or generation due to available capacity & fault level issues.
- **Moreton 66/11kV** - only able to accept a maximum of 3.17MVA of new connections or generation due to fault level issues.
- **Brackley Town 33kV** - only able to accept a maximum of 4.55MVA of new connections or generation due to fault level issues.
- **Calvert 33/11kV** - unable to accept additional demand or export connections due to the number of existing connections (both generation & demand).
- **Steeple Claydon Primary** - unable to accept additional demand or export connections due to the number of existing connection (both generation & demand).

  Note – where the capacity is listed as available this is not an indication that several connections could be made. If a capacity of 5MW was connected to Shipston 33/11kV for example, this would reduce the surrounding connection availability by the same amount at all other substations due to the upstream effect. This would mean for example Epwell 33/11kV would have no generation capacity available. This is due to the substations being connected to the same 33kV network supplied from Brackley 132kV BSP.

6.2 SSE substations

There are eleven SSE substations which have an influence on the Cherwell District Council geographical boundary.

- **Headington** - able to accept a maximum of 20MVA of new connections or generation due to available capacity, reverse powerflow capability of the transformers (50%) & fault level issues.
- **Headington BSP** – heavily constrained, fault level almost at maximum rating 12.49kA against a maximum of 13.1kA. No generation connection was possible.
- **Yarnton** - unable to accept additional export connections due to upstream (higher voltage) constraints. No generation connection available.
- **Arncott** - unable to accept additional export connections due to upstream (higher voltage) constraints and thermal limit (conductor and/or cable size). No generation connection was available.
- **Upper Heyford** - unable to accept additional export connections due to upstream thermal limitations. Limited expansion space for Circuit Breaker extension connections (very small site). No generation connection was available.
- **Bicester** - unable to accept additional export connections due to upstream (higher voltage) constraints and thermal limit (conductor and/or cable size). No generation connection was available.
- **Bicester North BSP** - Constrained due to 132kV thermal limitations under FCO (Fault Current Operation). Close proximity to thermal rating on Bicester-Bicester North 33kV circuit. No generation connection was available.
- **Kiddington** – constrained due to voltage issues (exceeding statutory voltage limits). No generation connections were available.
- **Lovelace Road** - constrained due to upstream thermal limitations. Limited expansion space for CB connections. Only 50% reverse powerflow capability – max 6MW without other restrictions.
- **Cottisford** - constrained due to upstream thermal limitations (conductor and/or cable size). No generation connection was available.
- **Deddington** - unable to accept additional export connections due to upstream (higher voltage) constraints and thermal limit (conductor and/or cable size). No generation connection was available.

6.3 UKPN substations

There is only one substation which has an influence in the Cherwell District Council geographical boundary.

- **Thame Primary** - unable to accept any generation due to the type of directional overcurrent protection that is installed.

6.4 Results

As it can clearly be seen from the substation information only one Substation in the Cherwell District Council area is capable of catering for a connection of 18MW to support the proposed photovoltaic development. SSE have offered a connection on the Bicester – Headington 33kV feeder. This connection is very close to the maximum allowable at Headington Substation and is realistically the last significant generation connection that will be made in the Cherwell District Council area for the foreseeable future.

7 33kV feeder route

The Bicester – Headington 33kV (black & white) feeder runs from Bicester to Headington. The start and finish points are as shown within Figure 2 and Figure 3 below -

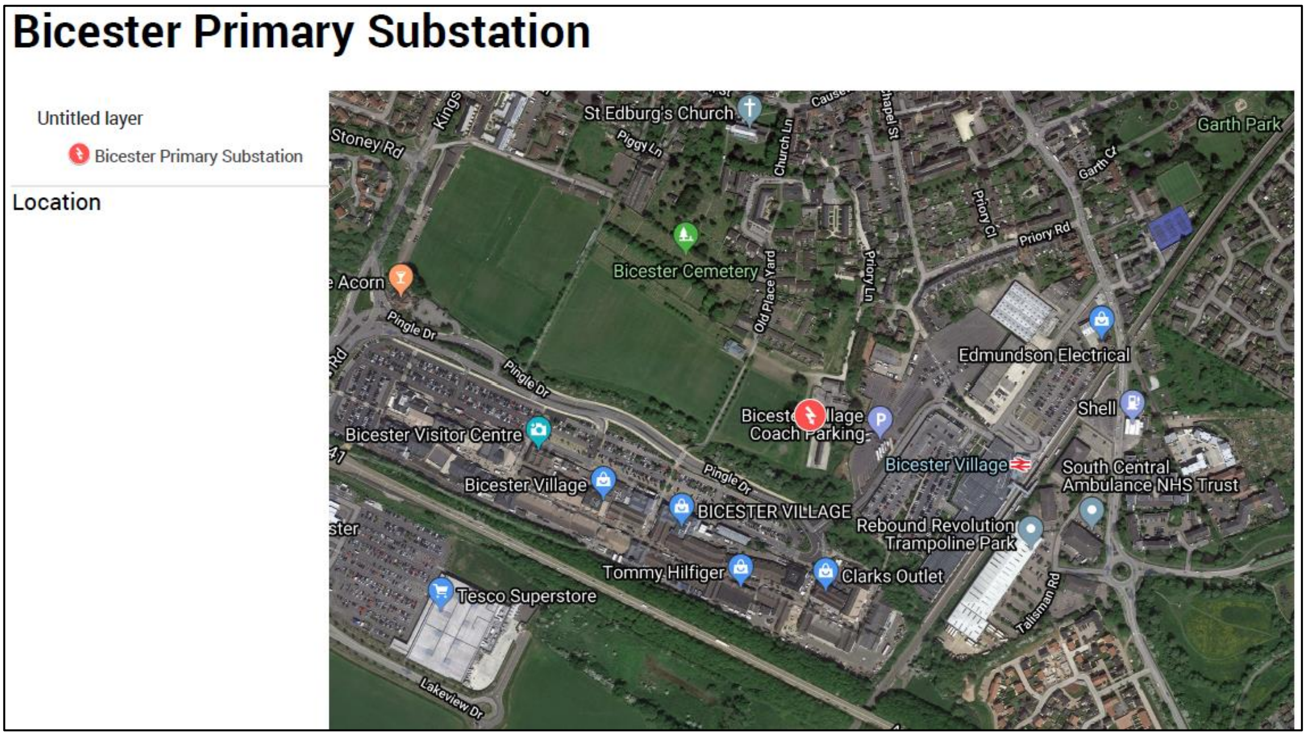

Figure 2: Bicester primary substation courtesy of Google maps

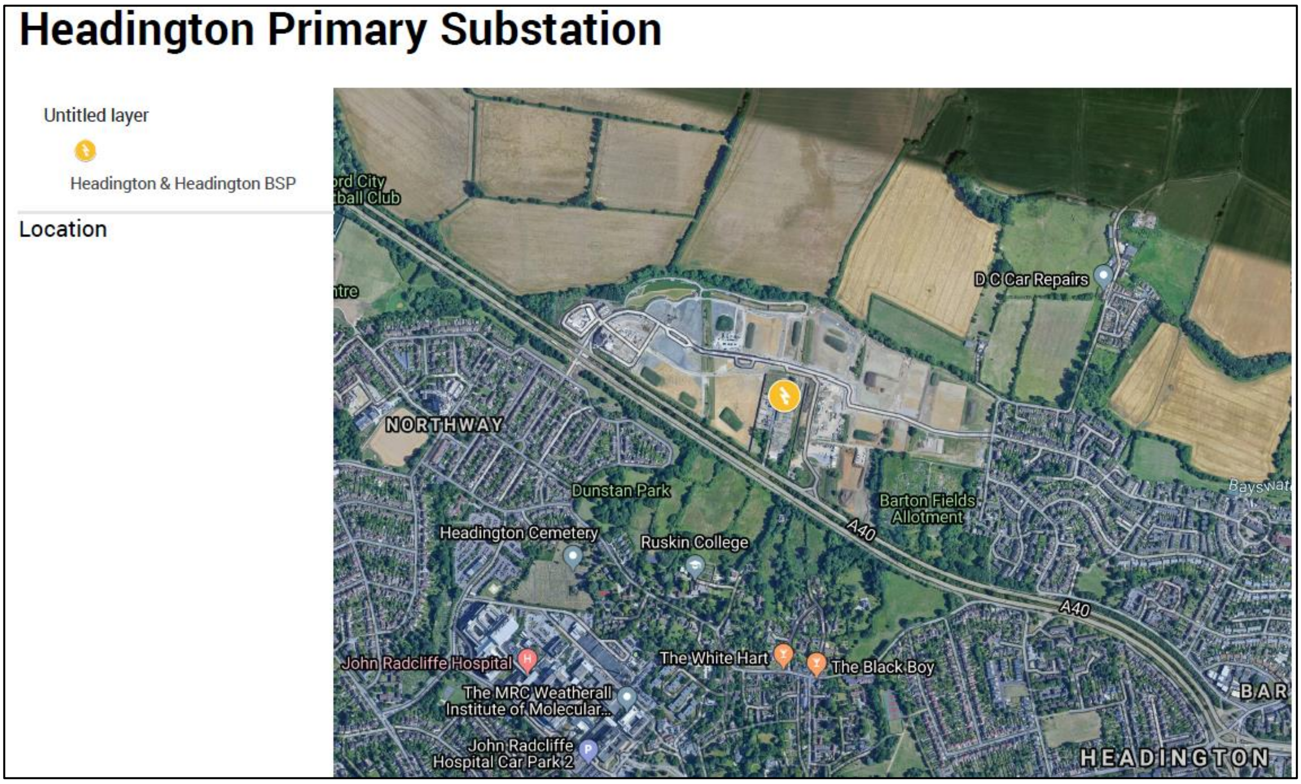

Figure 3: Headington primary substation courtesy of Google maps

The Bicester – Headington (black & white) 33kV feeder Figure 4, is a double circuit feeder and is a mixture of overhead lines (OHL) and underground cables (U/G) and is a link between the two Primary Substations. It's sister feeder is the Bicester – Headington (black & blue) 33kV feeder, which operates totally independently of the black & white feeder. Bicester Substation is unable to accept additional export connections due to upstream constraints and thermal limits (see section 6 for details). This means that a NOP (Normal Open Point) is to be established by SSE at Bicester Primary Substation so that the supply is always provided by Headington Primary Substation. This is a standard operational procedure for a DNO to perform and all HV circuits operate this way with an open point at some part of the circuit. This is for safety reasons so that in the event of a failure the point of the fault is not supplied from two directions, increasing the inrushing current.

Note – only one of the circuits, in this case the black & white feeder is suitable for an 18MW export connection.

Figure 4: Bicester – Headington 33kV feeders courtesy of Google maps

The Route which is within the boundary of Cherwell District Council is shown on separate maps provided by Pegasus. The circuit enters Cherwell District Councils area to the South around the Woodeaton area and heads North as an OHL, crossing Mr Pelton's land. Shortly after leaving Mr Pelton's land the OHL transitions underground until it has crossed the railway line at Kidlington level crossing. A connection to a 33kV cable will not be financially viable due to the significant extra costs of plant and equipment required, relative to an overhead connection. At this point the circuit continues adjacent to the railway line as an OHL.

The area which borders the railway line on each side is unsuitable for the installation of a large-scale source of generation. This is due to an electrical phenomenon called Rise of Earth Potential (RoEP). This is a situation whereby a large generator can impart a voltage through the surrounding mass of earth which can affect other equipment, in this case railway signalling equipment. To ensure this does not happen establishing a generation connection in this zone should be avoided. This will ensure that in the event of an incident or fault at the solar farm stray voltage does not adversely affect the adjacent railway. Further technical guidance on this subject can be found in EREC S34, EREC S36, BS EN 50522, ENA 41-24, EC61508 and IEC/TS 61000-2:2008 and chapter 8 of this report.

The existing overhead lines that are constructed in this area are built to an unearthed construction so do not pose a hazard from an RoEP perspective. A generator would need to establish a single point of earthing which will need to fully consider imparted voltages and a full earthing study for the site will be required in due course as part of the construction process.

The OHL then transitions to an underground cable shortly after running parallel with the railway line. From this point onwards an electrical connection will not be viable as previously discussed.

This therefore leaves a very small pocket of land suitable for an 18MW solar farm, the bulk of which is on Mr Pelton's land.

8 Rise of Earth Potential – RoEP

A rise of earth potential is caused by electrical faults that occur at electrical substations, power plants, or high-voltage transmission lines. In the event of a fault, short-circuit current flows through the plant structure and equipment and into the earthing electrode. Since the local Soil Resistivity is not zero Ohms and has a resistance value of 'X' Ohms then any current injected into the earth at the earth electrode position produces a Rise of Earth Potential or RoEP, Figure 5. This earth potential rise is concerning and can cause hazardous voltages, often many hundreds of metres away from the actual fault location. Therefore, many factors determine the level of hazard Including available fault current, voltage, soil resistivity and underlying rock layers. Rural 33kV substations can be problematic to earth safely. Problems can arise from sites that are fed entirely, or in part, by overhead line. This provides no return path for the fault current via a cable sheath for example, which is instead injected into the ground. Another consideration is the clearing time to interrupt the fault, also known as circuit breaker operating time or clearance time.

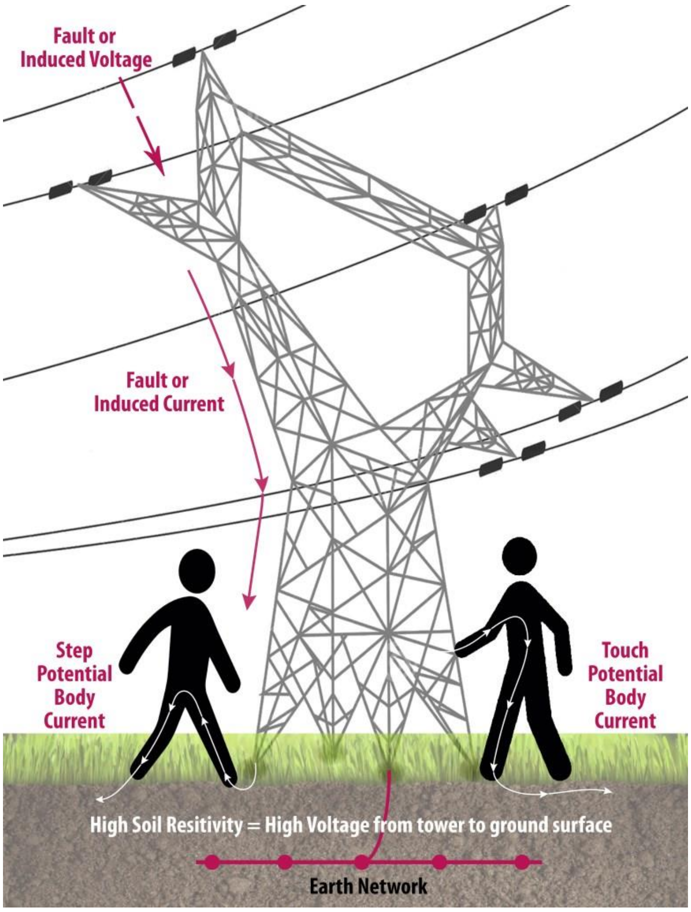

Figure 5: Indicative RoEP diagram courtesy of Greymatters

The rise of earth potential is a safety issue in the co-ordination of power and telecommunications devices, including railway signals. A RoEP event at a site such as an electrical distribution substation and it's greater connected network (ie a solar farm and it's associated panels & mounting framework) may expose personnel, users or structures to potentially hazardous voltages. This risk is mitigated by avoiding areas where an imparted voltage may cause issues, in this instance by locating the solar farm away from the railway line. The effects of RoEP are similar to the effect of a stone thrown into a still lake. The voltage gradients decrease like ripples until the voltage imparted is minimal. Note that this can easily be hundreds of meters and the higher the voltage the greater the ripples spread.

See Figure 6 below, –

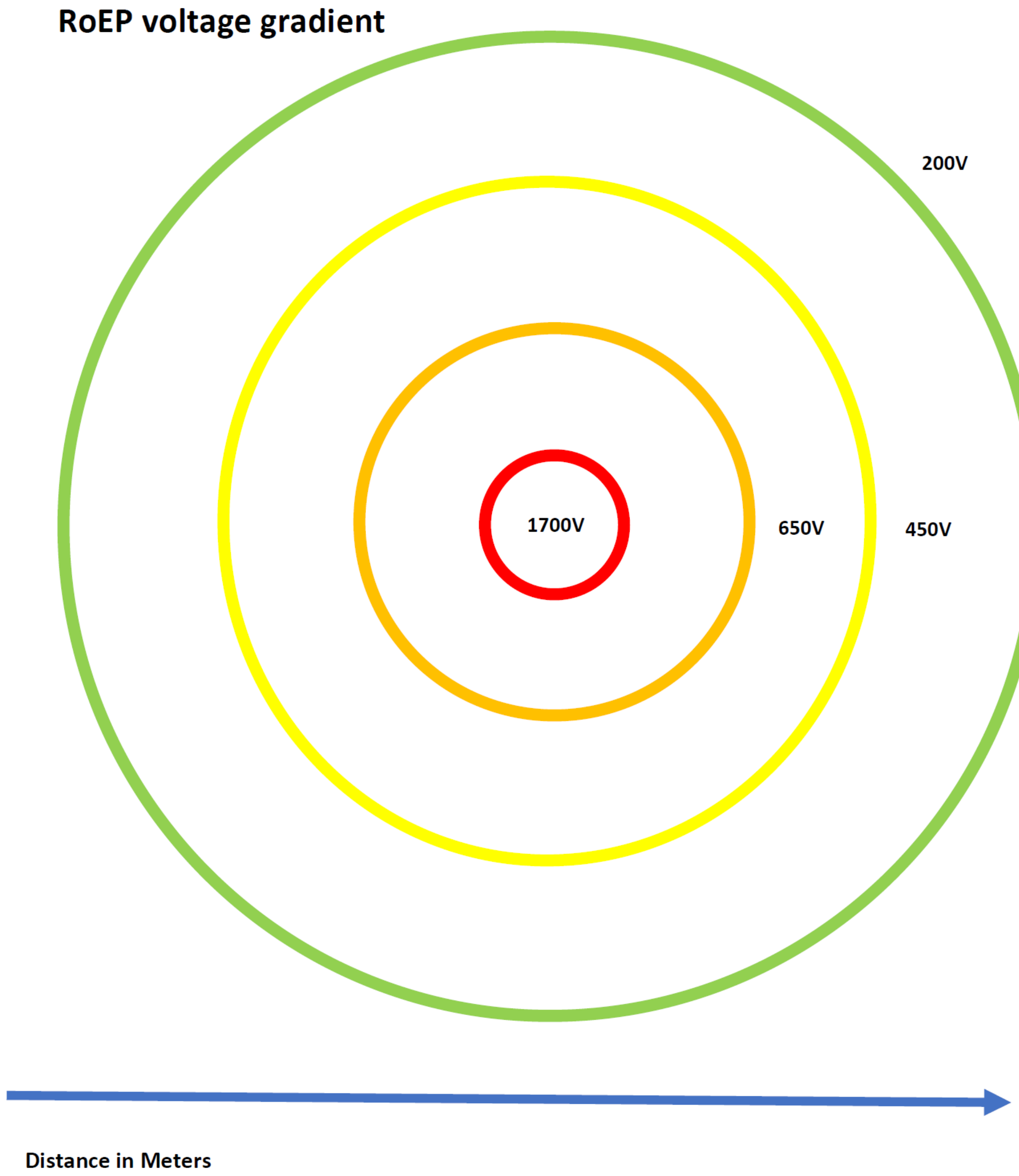

Figure 6: RoEP gradients

An extract from EREC S36 states –

Special precautions must be taken with telecommunication plant and strict working procedures adopted in the immediate vicinity of substations where the rise of local earth potential could, under the most severe earth fault conditions, exceed 430V rms. The limit of 430V may be extended to 650V rms if the power circuits contributing to the earth fault currents are high reliability type, having an operating voltage of 33kV or greater and controlled by switchgear with main protection that will clear both a line or busbar earth-fault current within 500ms and generally within 200ms.

On top of the requirements from the DNO side to reduce any RoEP infringements the railway network will have it's own standards and limitations and will also have a voltage gradient which could extend into the same zone we have identified. Assessment of this is beyond the scope of this report but should be taken into consideration. However, as with anything electrical where there is any form of doubt avoidance is always the best option.

Just because an existing solar farm is located near to a railway line does not mean that it is safe! The phenomena of RoEP has only relatively recently been recognised as an issue and it is quite possible that it may not have been considered at all. The regulation in place at the time of it's construction may well not have been as onerous as they are today, allowing for the site to effectively ignore the impact of RoEP. Current standards ensure that all new installations are safe, resilient and reliable under all fault condition scenarios.

9 UK predicted electrical demands

The following data is evidence that the UK's DNOs are preparing for a significant increase in demand over the coming years. The reduction in 'baseload' generators such as coal & gas means that renewable energy generation and battery storage facilities will play a larger and more critical part in the UK's electricity network.

Any form of renewable energy is important, and the installation of PV farm not only helps to reduce the amount of generation required to be produced by non-renewable means (mainly gas) but also reduces the carbon footprint of the UK grid. Solar is particularly relevant as it generally operates when the demand is high on the UK network – during the hours of daylight. As more and more customers are installing air conditioning to shops, factories and offices the day load will continue to grow.

Below is a typical time of use graph indicative of the UK's electricity network. As it can be seen the demand drops off after midnight before rising steadily through the day, finally peaking between 16:00 and 20:00. The demand then steadily tapers off towards midnight.

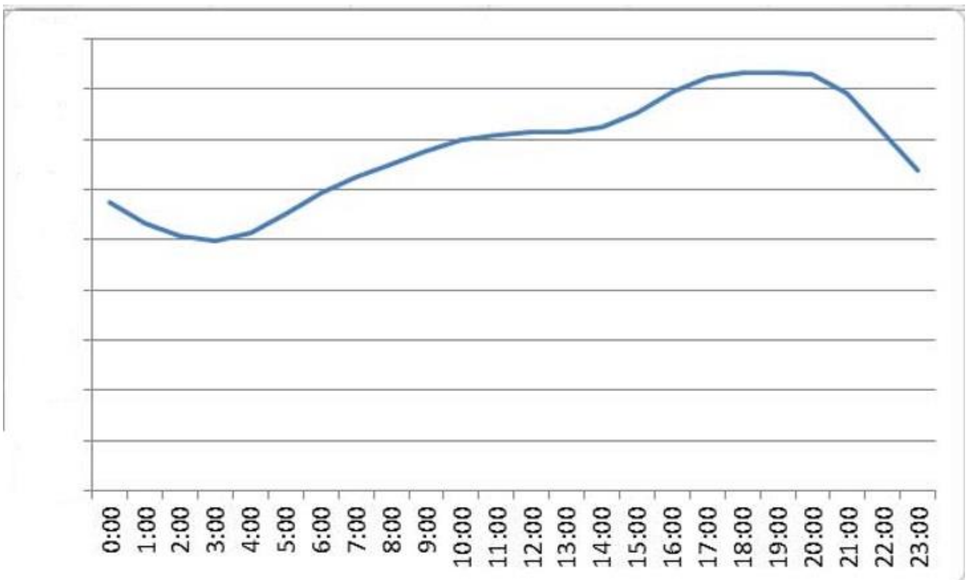

Figure 7 UK Time of use graph, courtesy of Ofgem

A typical solar farm output follows a similar path, but with a slightly higher midday peak. However, a PV farm which has been 'oversized' (oversized means more PV panels than output inverters) to maximise generation has a much 'flatter' output and produces peak output sooner and holds on to this peak output for longer. An example if this is within Figure 8 below –

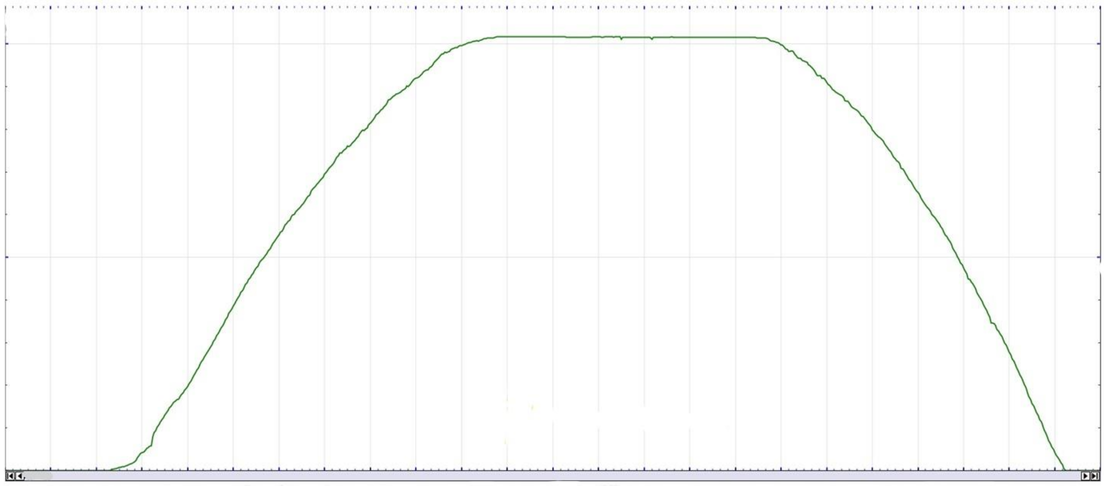

Figure 8: PV bell curve, courtesy of PV Education

This allows the solar farm to significantly reduce the need for non-renewable generation during operation periods, Figure 9.

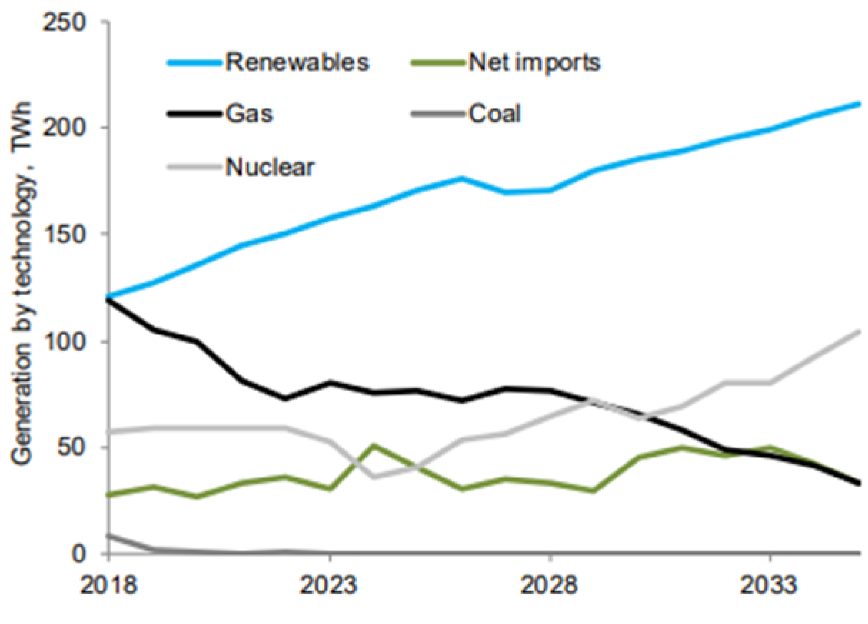

Figure 9 : UK electricity sources, taken from "Updated energy and emissions projections: 2018" (https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018)

In terms of the general trend, looking to UK government figures, renewables are predicted to continue to make up a larger part of the electricity grid in the future, as shown in figure 9 above. It is important to note that under various commitments, such as the Nationally Declared Contributions within the Paris Agreement and the targets of the Climate Change Act and associated carbon budgets, the UK will need to reach a significant amount of generation from renewable energy over the coming decade.

10 Greenhouse Gas reduction

One of the key advantages of establishing a solar farm in the Cherwell District Council area which must be given careful consideration is the reduction in the area's carbon footprint. As Cherwell District Council have declared themselves to be in a 'climate emergency' in July 2019 then the establishment of a means to significantly assist in reducing contribution to increased global warming and indeed reducing the Council's geographic area carbon footprint must be given the utmost priority. Solar Photovoltaic developments are one of the best and most economical ways to reduce the carbon footprint of electricity, due to the lack of moving parts faults are relatively rare (although the system must still have maintenance checks) and the present day failure rate of solar PV modules is just 5 in 10,000 panels (0.05%), this means the development will produce clean, renewable energy well into the future.

There are numerous ways to calculate the greenhouse gas savings from solar. We have taken a scientific approach, using the standard solar farm development software PVSyst, along with data from the Ecoinvent database, a major source of data for ISO 14040/14044 compliant Life Cycle Assessment (LCA) studies. Everything is calculated in terms of "Carbon Dioxide Equivalent (CO_{2eq})", showing the impacts of emissions over a full 100 years. This is a commonly used method, so that gases like methane and nitrous oxide produced during manufacturing are accounted for, as well as the carbon dioxide itself.

The adding of solar to the site will not result in the UK turning down solar, wind or nuclear. The only fully controllable variable output generator the UK has in terms of major percentage supply to the grid is Combined Cycle Gas Turbines (CCGT). Coal thermal power stations in 2020 are rarely used and the remaining few are all scheduled to close in 2025. Therefore, we have taken the carbon impact of electricity from a CCGT. This has been taken from the widely used industry standard Life Cycle Assessment (LCA) database Ecoinvent 3.5, using the IPCC 2013 Global Warming Potential (GWP100) figures. This impact considers not only the burning of the gas, but the full supply chain, through to the original extraction of the gas, and the building of the CCGT, therefore, this covers Scopes 1,2 and 3 in terms of standard UK metrics and additional impacts. This gave a figure of 0.3514 $kgCO_{2eq}$/kWh. There are also the losses in the electricity network to be considered, which are detailed within the Ofgem report "Electricity Distribution Systems Losses Non-Technical Overview" from 2012. Therefore, at the point of use, the impacts from gas-based electrical generation will be 0.3830 $kgCO_{2eq}$/kWh.

The above Ecoinvent and Ofgem data, with the above assumptions, was then used within PVSyst, which contains data on the environmental impact of the construction of all elements of the PV System, including degradation over the lifetime of the system. The full impact of the PV system per kWh over the specified lifetime was then compared with the baseline. Based on this methodology, the CO_2eq savings over a 25-year period of the system are calculated to be **69,660 tonnes**.

Note – at 25 years the system output will have reduced to approximately 80% of its initial installed value, approximately 14.4MW. This is still a significant figure and the site will continue to operate well. It is anticipated that even at 40 years old the site could still be producing a very useful 10MW, significant as the site will have offset its embedded CO_2eq impacts by year 5. This makes solar an excellent choice to help de-carbonise the Uk's electricity network alongside, offshore wind, onshore wind, hydro power and battery storage.

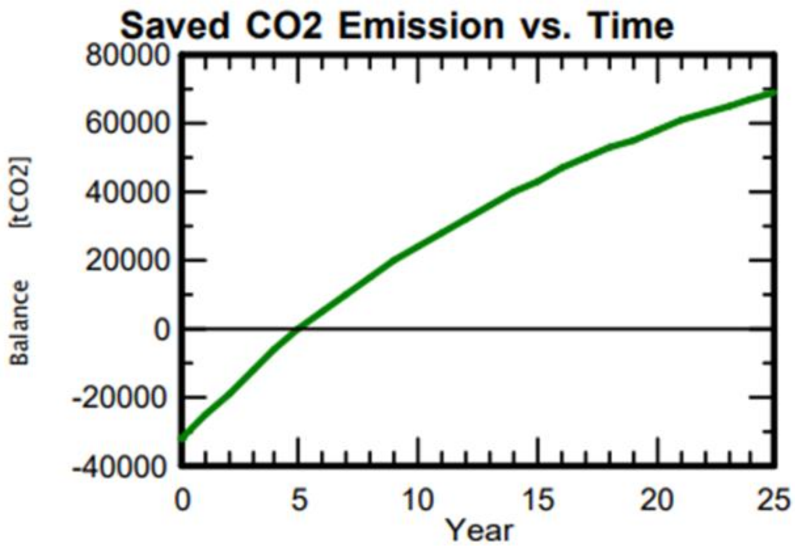

Figure 10: Output from PVSyst, showing the proposed 18,000kW (18MW) development will reduce carbon emissions by a total of 69,660 tonnes

11 Biodiversity

It is a well recognised fact that solar farms add to the biodiversity of the area and in fact help many species to not just survive but to actually thrive. Studies have revealed that solar farms can lead to an increase in the diversity and abundance of broad leaved plants, grasses, butterflies, bumblebees and birds.

A report written by Hannah Montag, Dr Guy Parker & Tom Clarkson entitled 'The effects of solar farms on local Biodiversity: a comparative study' gives a clear indication of the numerous benefits solar farms bring to the landscape.

Some key points of this report a summarised as follows –

- Botanical diversity was found to be greater in solar farms than equivalent agricultural land.
- Where botanical diversity is greater, this leads to a greater abundance of butterflies and bumblebees, and in several cases, an increase in species diversity too.
- Solar sites are particularly important for birds of conservation concern.
- By encouraging high abundances of bees and butterflies, solar farms can become net producers of pollinating insects.
- Solar farms are unique in the farmed landscape in that they provide a high value crop (solar power) while leaving the majority of the land area free for wildlife.
- Large numbers of brown hare were recorded within the solar farms compared with surrounding land. This is a species of conservation concern due to declines in numbers in many parts of the country.

Instead of being perceived as a detraction to wildlife, solar farms have shown themselves to be a safe haven for wildlife due to the relative lack of human interference in that area. The new habitat with shade & shelter allows some endangered species to thrive and prosper, leading to the increase in other native species as a result.

12 Conclusion

As we have shown there is only one viable connection point for an 18MW solar farm and it is just outside of the Cherwell District Council geographical area at Headington Primary Substation. From an electrical viewpoint the general area is heavily constrained, and the installation of battery storage may well help to reduce some constraints, although export (generation) constraints will still remain for the foreseeable future.

As the UK is attempting to head towards a carbon-neutral electricity network the installation of renewable energy is paramount to achieving this. The closure of the remaining UK coal-fired power stations over the next 5 years means that we are losing a significant amount of generation capacity (over 7GW) and we simply cannot have enough renewable generation. The low visible impact, silent operation and virtual lack of maintenance required to allow the system to operate at its full potential make this an ideal technology for the chosen location in Noke. One of the intrinsic advantages of solar panels is that they are a sustainable and clean source of electricity production, therefore they emit zero CO_2 because the process to generate electricity is done at the molecular level without the need to burn any component with carbon.

The added benefit of increased Biodiversity in the solar site will enhance the area's numerous species and will allow them to thrive in a safe and relatively undisturbed environment. The site may well attract new rare and genetically valuable species to the area too.

Solar is a key part of the UK's renewable energy strategy and this is a fantastic opportunity to help to reduce the carbon footprint of Cherwell District Council and assist in the Councils fight against the climate emergency they have declared.

The Fourth National Climate Assessment Report from the U.S Global Change Research Program, released in November 2018, has announced an alarming top date to make a significant impact on carbon dioxide reductions. According to the report, if CO_2 emissions are not cut 45% by 2030, then it will be unavoidable to reach 1.5°C increase in Earth temperature.

A range between 1.5°C and 2°C was established in the Paris Agreement, however, reaching 2°C would already mean reaching to worst climate change consequences, therefore, it cannot be seen as a threshold. Besides, the report concludes that by 2050 carbon emissions must be cut 100%, making a complete transition to renewable energy sources.

In light of the recent landmark decision by the Judiciary to ban the expansion of Heathrow Airport with a third runway because the Government had acted unlawfully by failing to take account of its commitment to the Paris Agreement on climate change in the National Policy Statement (NPS). This PV farm provides a golden opportunity to help assist in the UK achieving those targets and doing our bit as a country to try and prevent a climate disaster. The site will produce, clean, carbon free electricity for many decades to come and should be regarded as a valuable asset to the area.

Advancing
Renewable
Energy

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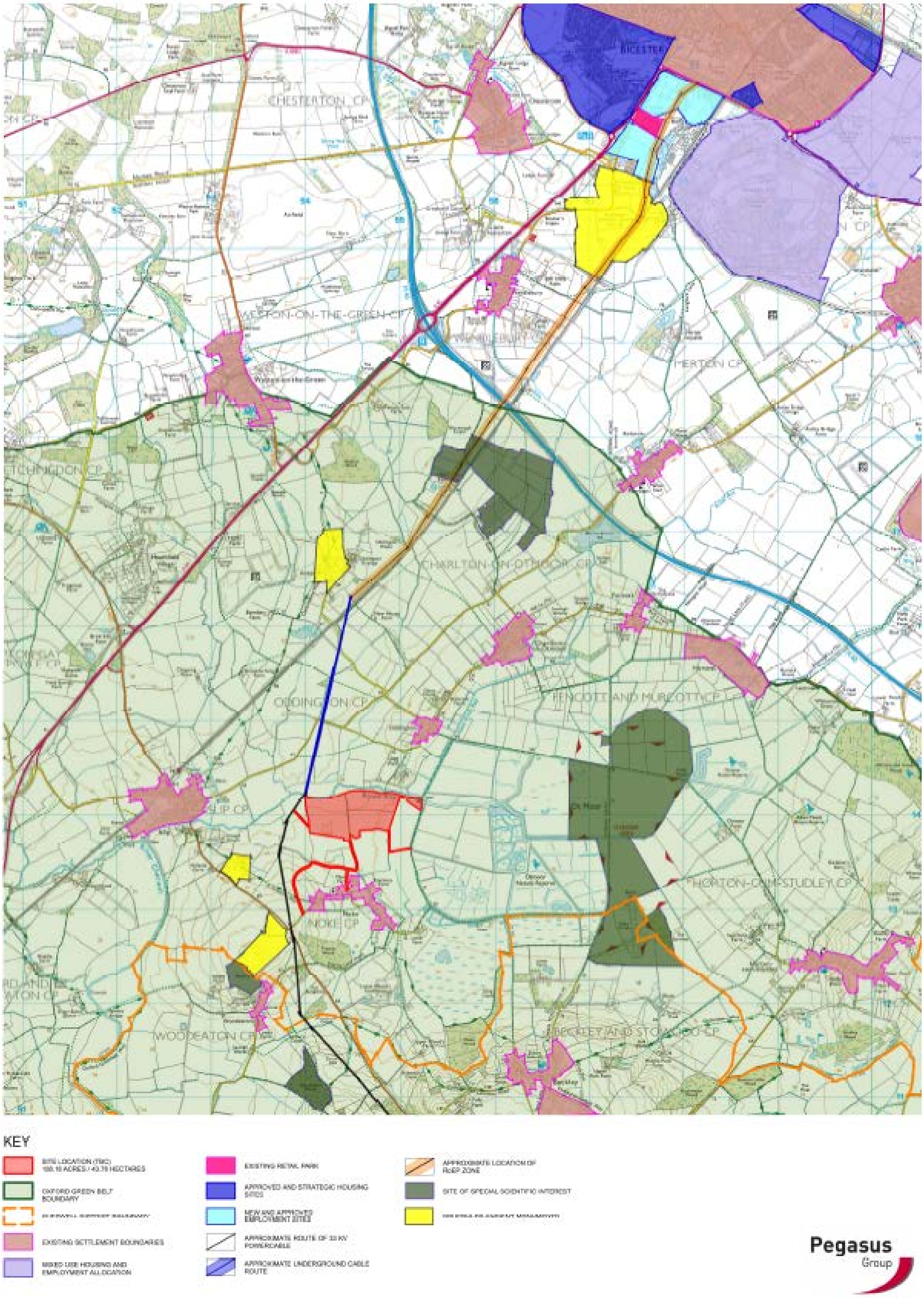
APPENDIX B- Pegasus Connection Power Line Constraints Map

GREEN NATION
SOLAR ENERGY



LAND AT MANOR FARM, NOKE - CONNECTION POWER LINE CONSTRAINTS MAP

PLANNING | DESIGN | ENVIRONMENT | ECONOMICS | www.pegasusgroup.co.uk | TEAM/DRAWN BY: RL | APPROVED BY: JW | DATE: 12/02/20 | SCALE: 1:25000 @ A2 | DRWG: P19-2636_004-1 REV: A | CLIENT: K.PELTON |