Heckington Fen Solar Park

EN010123

Technical Guide

Applicant: Ecotricity (Heck Fen Solar) Limited

Document Reference: 5.5
Pursuant to: APFP Regulation 5(2)(q)
Document Revision: 2

August 2023

Track Changes

Planning Act 2008

TECHNICAL GUIDE

Document Properties	
Regulation Reference	Regulation 5(2)(q)
Planning Inspectorate Scheme Reference	EN010123
Application Document Reference	5.5
Title	Technical Guide
Prepared By	Heckington Fen Energy Park Project Team (Pegasus)

Version History		
Version	**Date**	**Version Status**
Rev 1	February 2023	Application Version
Rev 2	August 2023	Change Application

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1 TECHNICAL GUIDE

1.1 INTRODUCTION

1.1.1 This Technical Guide has been prepared to support the Development Consent Order (DCO) application under the Planning Act 2008 for Heckington Fen Solar Park (hereafter referred to as "the Proposed Development") at Heckington Fen, Lincolnshire to the Planning Inspectorate.

1.1.2 The development will connect to the transmission network at National Grid's Bicker Fen substation, located some 5.5km to the south of the site (as the crow flies).

1.1.3 The purpose of this report is to explain ~~the~~ how the generating station and energy storage facility will operate and interact with the national grid electricity transmission network.

1.2 BACKGROUND

1.2.1 The Proposed Development comprises three elements, 1. the construction, operation, maintenance and decommissioning of a ground mounted solar park and energy storage facility with a design capacity of over 50 megawatts (known as the "Energy Park"); 2. an underground cable to National Grid's Bicker Fen Substation and 3. works to extend National Grid's Bicker Fen Substation – which is the point of connection. The three elements, together, are known as the "Proposed Development".

1.3 SOLAR PARKS- HOW DO THEY WORK, FROM SOLAR PV PANEL TO POWER?

1.3.1 Solar panels convert sunlight into electricity (DC) through a process known as the photovoltaic (PV) effect. The majority of PV solar panels currently deployed in solar parks around the world consists of a number (typically 60 or 72) of photovoltaic cells which are connected in series on the underside of a sheet of glass and held in place by an aluminium frame.

1.3.2 Each photovoltaic cell is a sandwich made up of two slices of a semi-conducting material – see **Figure 1** below. The most common semi-conducting material used in PV solar panels is silicon. Each layer has different electronic properties that energise when hit by photons from direct or indirect sunlight (e.g., light passing through clouds), creating an electric field.

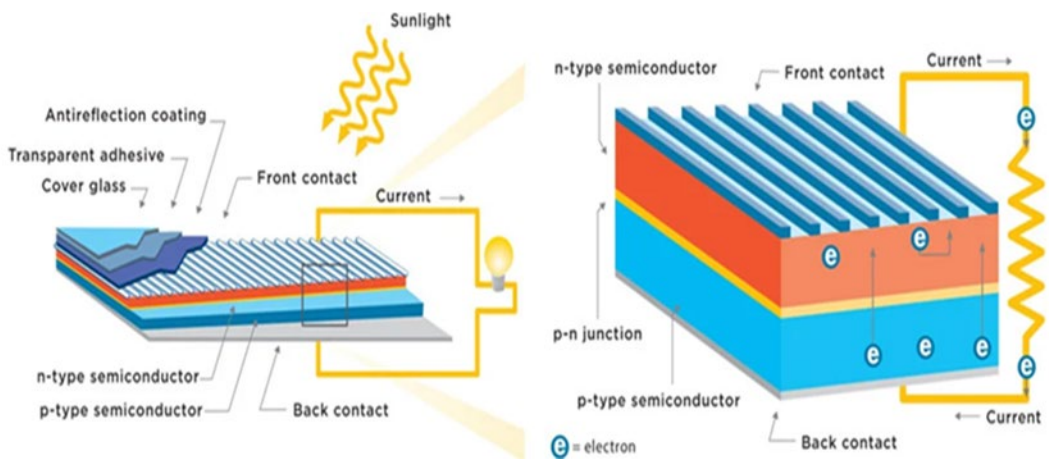

Figure 1- Cross Section of Solar Panel and Solar Cell

1.3.3 To create the electric field phosphorous is added to the top layer of silicon during the manufacturing process (creating a negative charge) and boron is added to the bottom layer (creating a positive charge). When sunlight hits the silicon molecules from both layers, an electron is knocked loose. These electrons are attracted to the top layer of silicon (the phosphorus layer) and repelled from the bottom layer of silicon (the boron layer). Metallic strips located along the top silicon layer collect the electrons. The metallic strips collectively join up with the metallic strips in all the other cells in the PV solar panel at the junction box located on the rear of the PV solar panel where the power cable that carries the electricity produced by the PV solar panel exits the junction box.

1.3.4 The electricity produced by the PV solar panels is a direct current (DC) converted to alternating current (AC) once the power leaves the junction boxes by an inverter. The electricity we use in our homes and businesses is AC and so must be converted from DC electricity to AC. The inverter completes the process by rapidly switching the direction of the DC input back and forth resulting in an AC output and the electricity is now in a useable form for homes and businesses. Inverters come in various sizes from small 'string' inverters (see **Figure 2** below) that sit under the PV solar arrays to the larger 'central' inverters (see **Figure 3** below) which are located throughout a solar park.

Figure 2- String Inverters

Figure 3- Central Inverters (including 33kV transformer)

1.3.5 With the electricity converted to AC it is still at low voltage and this must be increased to match the voltage at the Point of Connection (PoC) of the local electricity network. The voltage at the PoC will vary by solar park and will typically be one of 11,000V, 33,000V, 66,000 or 132,000 or 400,000V (Volts). A grid connection has been agreed between National Grid and the Applicant, with electricity to be supplied directly into the national electricity transmission network operated by National Grid. The voltage at the PoC (Bicker Fen Substation) is 400,000V (also referred to as 400kV). Heckington Fen Solar Park will connect into a new substation extension at the existing Bicker Fen National Grid Substation. The connection to Bicker Fen Substation will be provided via a 400kV underground cable from the Energy Park. The onsite substation will export at 400kV AC with an agreement in place with National Grid for 400MW export, and 250MW import. 1000 volts is also known as a kilovolt (kV), and the numbers above are often shortened to 11kV, 33kV, 66kV, 132kV and 400kV. The voltage at the PoC (Bicker Fen Substation) is 400kV.

1.3.6 To achieve the increase in voltage required a series of transformers are used across the solar park to increase the voltage from the outputs of the inverters to the site distribution voltage of 33kV or 66kV (**Figure 4** and again to the connection point voltage of 400kV (**Figure 5**).

Figure 4 - 33kV or 66kV Transformer

Figure 5 – 400kV Transformer

1.3.7 Following completion of the connection to the national electricity transmission network, the electricity produced by the solar park is free to travel around the transmission network, and into the local electricity network. The electricity produced will support ensuring the safe operation of the electricity network in the UK.

1.3.8 Typically, the electricity will be used locally however the actual electricity produced may be purchased by a company in another part of the UK as part of a Corporate Power Purchase Agreement (‘PPA’). PPAs from renewable energy sources are increasingly seen as viable options for corporate entities to reduce their carbon footprint whilst also being able to purchase electricity directly from the producer. These arrangements create a win-win situation for both the corporate entity and the operator of the solar park, and the network operators secure a payment for the use of their network to transmit the power.

1.4 SOLAR PANEL TYPES

1.4.1 Solar panel types available on the commercial market include:

i. Solar Thermal Panels: These types of panels convert solar energy into heat that is then used to warm the water within a cylinder (see **Figure 6** below), rather than converting the sun's energy into electricity. They are less sophisticated using the direct heating of water (or other fluids)

Figure 6- Solar Thermal Panels

by sunlight. For domestic use, solar thermal panels are installed on a roof facing the sun, heating water stored in a hot water cylinder and so providing hot water and heating. On a larger scale, solar thermal can also be used in power stations.

ii. Monofacial Solar Panels: These are the traditional form of solar panels with only solar cells on one side of the panels. They absorb the sun's energy from one photovoltaic side and convert it into electrical energy for charging electronic appliances.

iii. Bifacial -Solar Panels: Bifacial solar panels (see **Figure 7** below) have cells on both sides to capture what is known as the albedo off the surface over which the panels are erected. The albedo is a dimensionless quantity and is usually expressed as a percentage — the higher the reflectivity of a surface, the higher its albedo. For example, a black surface that absorbs a large amount of light has a low albedo, while a white surface that reflects a large amount of light has a high albedo. Increases in output when placed over grass is around 5%, when placed over a white-painted surface a 22% increase in output can be achieved.

Figure 7-Bi-Facial Panel

iv. Half Cell PV Solar Panels: Half Cell panels (see **Figure 8** below) use cells that are cut in half thus reducing the resistive losses and improving the panels performance. Half cut cells are also more durable because they are less prone to micro cracks given their smaller size. One other advantage of half-cell panels is that they work better in shaded conditions compared to conventional panels. If some cells in a conventional panel are in shade this can affect many of the cell rows due to the way in which conventional panels are wired and a reduction in the output of a panel will occur however with half cut cell panels there are more rows of cells and additional wiring so the same amount of shading will result in less reduction in output.

Figure 8- Half Cell PV Solar Panels

v. Tracker Systems: Tracker systems (see **Figure 9** below) enable the panels to track the sun as it crosses the sky initially pointing to the east in the early morning, reaching due south by midday and turning to the west in the evening. This cycle repeats itself on a daily basis.

Tracker systems are very common in locations where the sunlight levels are high e.g., California, Spain etc. where the additional costs to install the tracker systems are offset by the increased output from the panels. Whilst not common in the UK at present a small number of recent PV solar parks have utilised tracker systems in the design.

Figure 9- Tracker System

1.4.2 The Proposed Development is using Bi-facial panels; the other solar panel technologies have been disregarded through the design process of the Proposed Development. Tracker system solar panels were considered for Heckington Fen Solar Park in the Preliminary Environmental Information Report but were subsequently ruled out.

1.4.3 The overall design of each PV solar park is different and a design that works on one site may not be suitable for another due to a number of factors e.g., topography, location, grid connection characteristics, field layouts etc. The newer technologies will have higher outputs and efficiencies but will not always be the right solution and each PV solar park goes through a rigorous design process before deciding on the type of panels to use.

1.5 MEGAWATT AND DC/AC

1.5.1 The Heckington Fen Solar Park is expected to comprise around 500MWp of solar panels. Megawatt peak (MWp) is a term used to measure power and is equivalent to a million watts.

1.5.2 The units MWp describe the installed solar panel capacity of a solar park. However, they don’t describe how much electricity is produced in a specified period of time - the energy output of the solar park, or yield. This quantity is described in kilowatt-hours (kWh) or megawatt-hours (MWh).

1.5.3 A solar panel which is rated 1MWp is capable of supplying one million watts of power for one hour, which can be shortened to one megawatt hour (1MWh) or 1,000 kilowatt hours (kWh). The conditions in which the solar panel is capable of reaching the rated level, e.g., 1MWp is likely to vary geographically, for example closer to the equator the conditions are likely to be more optimal and solar panel is likely to reach its rated level more frequently.

1.5.4 A solar park is also designed to be as economic as possible and so the AC infrastructure is sized to deliver the most energy output (in MWhr) whilst balancing the costs. As a result, it is normal design practise for the Total Installed Capacity (measured in MW) to be slightly less than the MWp of a solar park as the peak output only occurs for short periods on the sunniest days. Heckington Fen Solar Park will be able to export up to 400MW of renewable generation to the National Grid.

1.5.5 The energy storage at Heckington Fen Solar Park is expected to have an output capacity of 200-400MW, with a storage capacity of up to 800 megawatt hours. The energy storage at Heckington Fen will be able to charge from the Solar generation and by importing up to 250MW of power from the National Grid. For discharge, the energy storage will be able to export up to 400MW of power to the grid.

1.5.6 It is important to note that the agreement with National Grid is to export no more than 400MW and import no more than 250MW. With the Solar and Energy Storage capacities exceeding this value there will be a control system which limits the power flows to within the agreed limits. The solar and storage will be fully controllable to maximise solar generation and provide the energy shifting and network support that storage delivers.

1.6 GENERATION FOR HOMES AND EMISSIONS

1.6.1 A calculation can be run to estimate the number of homes the Proposed Development could power, this uses the export capacity of 400MW AC to be conservative. The annual generation for a solar park of this size could generate approximately 385 gigawatt-hours (GWh) of renewable electricity per year, calculated as:

Table 1- Heckington Fen Solar Park Approximate Annual Generation (GWh)

400,000kW	x	8,766	x	0.11	=	385,704,000 kWh
400MW x 1000		Number of hours in a year 365.25 days to account for leap years x 24hours		Calculated using a Capacity Factor* sourced from DUKES averaged over five years, (BEIS 2021)		Or 385,704 MWh Or 385 GWh

1.6.2 Based on this annual electricity generation figure of 385 GWh, it is estimated that the Proposed Development could supply renewable electricity equivalent to the approximate annual domestic needs of over 100,000 typical UK households per annum.

Table 2- Heckington Fen Solar Park Approximate Annual Generation (Homes)

385,704,000kWh	÷	2,900 kWh	=	133,001
As calculated above		Based on Ofgem Typical Domestic Consumption Values		Typical UK households per annum
385,704,000kWh	÷	3,772 kWh	=	120,254
As calculated above		Based on BEIS Electricity Consumption Figures		Typical UK households per annum
385,704,000kWh	÷	3,952 kWh	=	97,597
As calculated above		Based on BEIS Electricity Consumption Figures		Local average of electricity supply for North Kesteven

1.6.3 * 'Capacity Factor', or load factor, is a term often used to consider the performance of solar parks (and other forms of generation). It means how much electricity a site generates in a year compared to how much electricity could theoretically have been generated if it were producing at maximum output continuously. An industry standard is to use an average capacity factor over five years for the purposes of these calculations.

1.6.4 Estimated carbon dioxide (CO_2) savings can be predicted using the current grid mix and the generation figure provided above. The current grid mix comprises all fuels, including nuclear and renewables. The 2022 figure is 192 tonnes of CO_2 per GWh of electricity supplied (BEIS), meaning the Proposed Development could result in a yearly saving of 74,055 tonnes of CO2- see Table 3.

Table 3- Heckington Fen Solar Park Approximate Annual CO_2 Savings

385,704,000kWh	÷	1,000,000	x	192	=	74,055
As calculated above		kWh to GWh		Grams of CO_2 per GWh		Tonnes per year

1.6.5 The calculation for the equivalent number of cars being taken off the road is useful to help put this into context only.

1.6.6 HyNet[1], a low carbon and hydrogen energy project across the North West and North Wales, calculated that by 2030 they would reduce carbon dioxide emissions by 10 million tonnes every year – the equivalent of taking 4 million cars off the road. Using this equation, 10,000,000 divided by 4,000,000 results in 2.5 tonnes per car. To make this site specific to Heckington Fen Solar Park, 75,000 tonnes divided by 2.5 results in the equivalent of 30,000 cars.

1.7 HISTORY AND FUTURE OF SOLAR PANELS

1.7.1 The first photovoltaic cells were produced in the 1950s and for many decades were considered too costly for a widespread roll out. In 2000 Germany introduced a 'Feed in Tariff' which aimed to promote the development of solar to assist in reducing greenhouse gas emissions. The program was a success and helped develop the global PV solar panel manufacturing industry that we see today. Other countries quickly followed, and the number of solar panel manufacturers increased rapidly to match the global appetite. The majority of the manufacturers are currently based in China, however there are others in Japan, Malaysia, Taiwan, South Korea, the USA and Germany.

1.7.2 Due to the amount of competition in solar panel manufacturing marketplace there is a constant race for manufacturers to increase the panel output and efficiency. Efficiency is the percentage of sunlight that hits the PV solar panel and is converted into useable electricity. To put this in some context in 2010 when the UK introduced its 'Feed in Tariff' solar park design typically used panels with an output of between 250 – 300 watts peak and an efficiency of c.14%.

1.7.3 Today it is common to see project designs using panels with outputs 400 – 500Wp and efficiencies of circa 21%. Some manufacturers have recently introduced panels with outputs over 600Wp and whilst not mainstream currently it is likely that these higher outputs will start to be used in project designs over next 12 – 18 months. In laboratory testing efficiencies of >40% have been recorded however these have not been achieved in mass production.

[1] https://hynet.co.uk/wp-content/uploads/2022/09/08092022-Chris-Skidmore-visits-HyNet.pdf

1.8 ENERGY STORAGE SYSTEMS- HOW DO THEY WORK AND WHAT ARE THE BENEFITS OF CO-LOCATING WITH A PV SOLAR PARK?

1.8.1 An Energy Storage System (‘ESS’) is a device that is charged by collecting energy from a power plant or the grid and then discharges that energy at a later time to provide electricity or other grid services when needed. National Grid now consider ESS an essential technology that will play an increasingly pivotal role between renewable energy supplies and responding to electricity demands[2].

1.8.2 There are a number of different technologies currently in use:

i. Lithium-Ion Batteries: Lithium-Ion (‘Li-ion’) batteries are currently considered to be the most cost-effective electricity storage solution. Li-ion batteries were first produced in the early 1990’s and were widely used in consumer products from this time. As Li-ion batteries are extremely versatile in terms of in size and scale they can be used in small consumer products in addition to utility scale ESS and this versatility has made Li-ion batteries the dominant technology in ESS. This coupled with the reality that to transition to low carbon electricity production, battery storage will be required to deal with the challenge of matching demand with the intermittent supply from renewable energy technologies has led to a massive increase in the production of Li-ion batteries across the globe. This increase in production has led to dramatic cost reductions of c85% over the past 10 years.

   Li-ion batteries are formed of a series of cells with each cell having the following components – a positive electrode (cathode), a negative electrode (anode), a separator and a chemical electrolyte. The anode stores the lithium and is typically made from carbon. The cathode also stores the lithium and is made from a chemical compound that is a metal oxide – typically lithium iron phosphate is used in the newer Li-ion batteries. The separator blocks the flow of negative and positive electrons inside the battery but allows lithium ions to pass through. The electrolyte sits between the two electrodes, and it carries the positively charged lithium ions from the anode to the cathode and vice versa depending on whether the battery is charging or discharging. The movement of the lithium ions creates free electrons in the anode which creates a charge. When the battery is discharging the lithium ions flow from the anode to the cathode and the process is reversed when the battery is charging – see **Figure 10** below.

[2] https://www.nationalgrid.com/stories/energy-explained/what-is-battery-storage

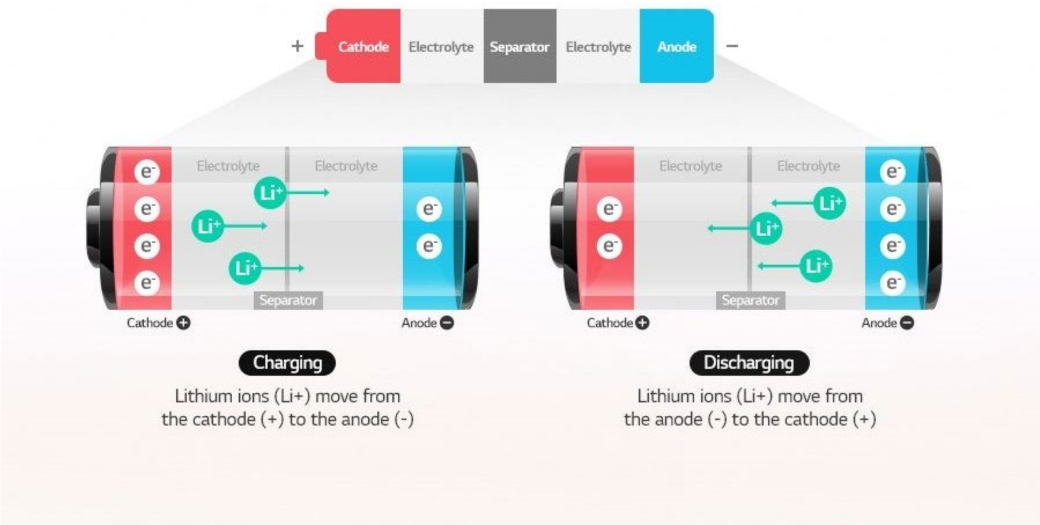

Figure 10- Lithium- Ion Battery Cross Section

ii. Redox Flow batteries: Redox Flow Batteries differ from conventional batteries in that the energy storage material is conveyed by an energy converter. This requires the energy storage material to be in a flowable form. The best-known representative of redox flow batteries today is the Vanadium Redox Flow Battery ('VRFB'). VRFB use various states of vanadium to store and release charges in a water-based electrolyte containing vanadium salts. The electrolyte is stored in two tanks which simply sit there until needed. When pumped into a chemical reactor, the two solutions flow adjacent to each other past a membrane and generate a charge by moving electrons back and forth during charging and discharging – see **Figure 11** below.

First invented in the 1980's the technology is lagging behind Lithium-Ion batteries in terms of deployment mainly due to higher costs. VRFB's are also considered to be more effective over longer durations of service e.g. 6hrs of charging/discharging however very few applications require durations of this length with typical grid service requirements being charging/discharging of 1 – 2 hrs.

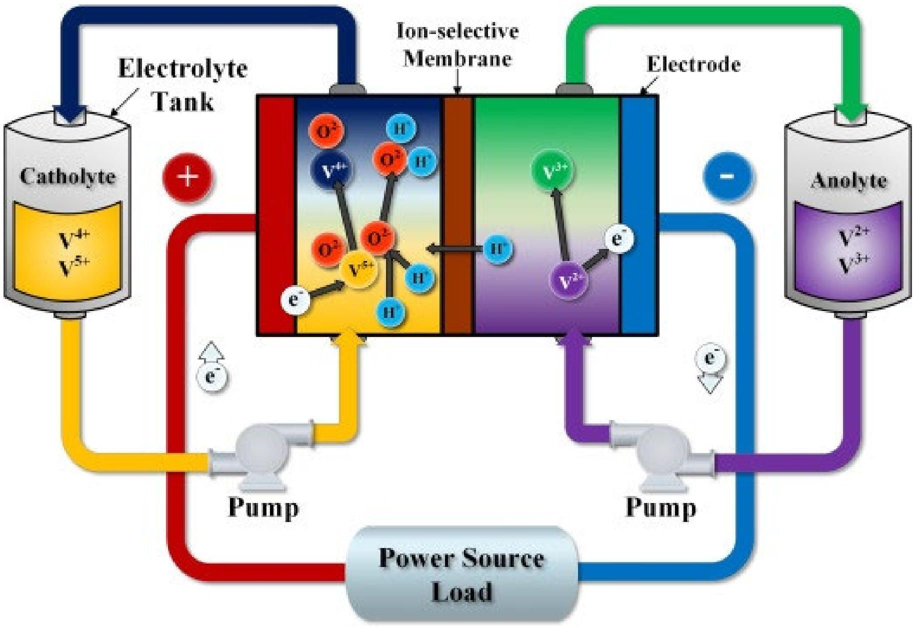

Figure 11- Redox Flow Battery Cross Section

1.8.3 Co-locating an Energy Storage System with a PV solar park creates many benefits with the technologies being complementary in many ways. Also referred to as 'hybrid-power plants' the introduction of ESS offers the solar park operator a number of options for the electricity produced. A traditional PV solar park would export the electricity produced to the local electricity network at the time it is produced but the addition of a BESS gives the operator the alternative strategy of holding on to that electricity and releasing it to the local electricity network later in the day.

1.8.4 In addition to the PPA's discussed in paragraph 1.3.6 the operator of a co-located BESS also has the following options for the electricity produced available to it:

i. Capacity Market: The Capacity Market was introduced by the UK Government in response to the increase in renewable electricity generators connecting to the electricity network. As renewable electricity generating stations are less predictable in terms of their generation profile the Government introduced the mechanism to provide an insurance policy against future blackouts e.g., in times of low generation and high demand. The Capacity Market works by guaranteeing payments to power plant operators for an agreed amount of electricity generation and those power plants must always be available at short notice to meet any request to supply electricity. National Grid calculate the potential shortfall in electricity production and annual auctions take place to secure the additional supply to ensure that blackouts do not occur.

ii. Ancillary Services- Maintaining System Frequency: The system frequency of the UK electricity network is 50 Hertz (Hz) and whilst it varies continuously National Grid's role is to maintain the frequency at 50Hz +/-1%. At times when demand is greater than generation the frequency falls and when demand is less than generation the frequency rises. Large deviations in frequency can lead to blackouts or in extreme cases grid failure where major repairs are required. On Friday 9th August

2019 lightning strikes caused two power stations to trip out and in less than 2 mins, 1800MW of generation came off the network causing the frequency to drop to 48.8Hz. As there was not sufficient backup generators available National Grid had no alternative but to immediately instruct District Network Operators to reduce demand by 5% which led to a blackout for c1 million customers for c40mins and impacted the transport network for the following two days. At times of increased generation, the frequency will increase beyond the 50Hz +1% range and this can lead to generation having to be switched off.

To avoid these scenarios National Grid, procure frequency response services on a weekly and monthly basis from power plant operators whereby National Grid can instruct the power plant operator to either consume or generate electricity at extremely short notice (can be as low as milliseconds) for short periods of time (typically no longer than 30 mins).

Dynamic Frequency Response is the pre-fault response programme which monitors frequency continuously and power plant operators either reduce electricity demand or generate a little more electricity as frequency varies above or below the 50Hz threshold.

Static Frequency Response (Non-Dynamic) is the post-fault response programme and requires power plant operators to either reduce electricity demand or increase generation very quickly when the frequency hits a pre-determined trigger level above or below 50Hz set by National Grid.

iii. Balancing Mechanism: In an ideal scenario there is 100% balance in the electricity network between generation and demand however due to forecasting errors and unexpected outages imbalances occur. National Grid is obliged to manage network imbalances and one of the methods of doing this known as the Balancing Mechanism. The Balancing Mechanism is a real time tool used by National Grid at half hourly intervals each day. Where National Grid predicts that there will be a discrepancy between electricity generation and demand during a certain time period, they may accept a 'bid' or 'offer' from a power plant operator to either increase/decrease generation or increase/decrease demand.

1.8.5 Technological advancements in remote monitoring and control of Energy Storage Systems ensure immediate response times are available when discharge of stored electricity is required during times of increased demand on the electricity network or when charging is required during times of over generation on the electricity network. ESS are perfectly placed to assist National Grid in ensuring the safe operation of the electricity network.

1.8.6 The remote monitoring and control systems within the ESS are also interlinked with the remote monitoring and control systems for the PV solar park to ensure the seamless operation of both technologies. The operator of a co-located ESS uses algorithms to co-ordinate electricity production and depending on what contracts the operator has entered into the electricity produced will either be exported to the local electricity network as it is produced, used to charge the ESS or used in part for both options. The quantities of electricity used for export/ESS charging will depend on the contracts entered into by the operator and the algorithms will ensure that a situation never arises where the ESS is fully charged, and the PV solar park is generating more electricity than can be exported.

1.8.7 With regard to the charging times for ESS from a PV solar park this will vary depending on the output from the solar park and also the loss in efficiencies across both technologies. For example, it would take up to 1.25 hours to fully charge a 100MW ESS system using a 100MWp PV solar park assuming that the solar park produced a constant 100MW for at least 1 hour. The time taken to fully charge the 100MW ESS will vary up or down depending on the output above or below the 100MW from the 100MWp solar park.

1.9 WHAT ARE THE ANNUAL MAINTENANCE REQUIREMENTS FOR A PV SOLAR PARK?

1.9.1 Once constructed and operational the viability of a PV solar park is dependent on how good the Operation and Maintenance ('O & M') program is. PV solar parks (other than those that utilise tracker systems) have no mechanical moving parts however they are complex power plants that require continuous monitoring to ensure that the solar park is operating at optimal performance levels. Technology has advanced to the point that monitoring of the solar park is completed remotely.

1.9.2 There are many companies active in the UK now that offer O & M services to the operators of solar parks. Typical services offered within O & M contracts are:

- 24 hr Remote Monitoring
- Output Data Analysis
- Performance Optimisation
- Preventative Maintenance
- Rapid Response to on-site Issues
- CCTV Monitoring and Security
- PV Panel Cleaning
- Maintenance of Vegetation in Co-ordination with Ecologists

1.9.3 The remote monitoring is typically completed using a Supervisory Control and Data Acquisition ('SCADA') system which allows monitoring and remote operation of the solar park via satellite. The constant feed of data allows the O & M companies to see if issues have arisen or if certain areas of the solar park are under-performing which may be due to damage, a build-up of dust or a defect in some of the PV panels or some other equipment e.g. inverters/transformers may be under-performing. A decision on whether a site visit will be required is made once the data received has been analysed.

1.9.4 Scheduled site visits would typically be undertaken once every 3 months to inspect the PV panels, mounting structures and electrical infrastructure and connections. Other site visits may be required if operational issues are encountered at any time. For Heckington Fen there will be O&M staff normally station at the site undertaking various O&M activities.

1.9.5 PV panel cleaning methods have advanced and depending on the size of the solar park may be completed using a small, tracked machine similar to the one in **Figure 12** below.

Figure 12- Solar PV panel Cleaning Method

1.10 WHAT HAPPENS TO THE PV SOLAR PANELS, ASSOCIATED ELECTRICAL INFRASTRUCTURE AND THE BATTERY ENERGY STORAGE SYSTEM WHEN THE SOLAR PARK IS DECOMMISSSIONED?

1.10.1 When the time comes to decommission a solar park the physical process of removing the equipment will begin. As the majority of the equipment is classed as electrical it will fall under the Waste from Electrical and Electronic Equipment Regulations 2013 ('WEEE'). WEEE was introduced to reduce the amount of waste electrical equipment sent to landfill/incinerated and to promote re-use, recovery and recycling of electrical equipment.

1.10.2 The electrical equipment used in a solar park and its suitability for recycling are listed below:

i. PV Solar Panels: Whilst PV solar panels have been around for decades their deployment on a global scale only commenced in the last 15 years. In light of this the decommissioning/recycling of panels is only starting to gather pace. Silicon based PV panels similar to those proposed for Heckington Fen Solar Park consist of approximately 76% glass, 10% polymer (encapsulant and back sheet foil), 8% aluminium, 5% silicon semiconductor, 0.9% copper (interconnectors) and 0.1% other metals silver, tin and lead (contact lines). The recycling process involves the following processes:

   a. physical disassembling of the panels (removal of frame and connection box) with the aluminium frames removed for recycling;

   b. cutting of the solar cells into small pieces;

   c. stripping of the semi-conductor films (silicon) from the glass in a rotating drum with the glass and polymer cleaned and removed for recycling;

   d. the remaining metal compounds are processed for re-use in the manufacturing of PV panels.

There are a number of avenues open to the operators with regard to recycling of the panels:

e. PV Cycle (www.pvcycle.org.uk) is a global not-for-profit organisation that offers waste management services for operators of solar parks. Initially set up to recycle PV solar panels it has expanded its services to include batteries and inverters. PV Cycle has achieved a 96% recycling rate for silicon-based PV solar panels.

f. Recycle Solar (www.recyclesolar.co.uk) is based in Scunthorpe and specialises in the recycling of PV solar panels and inverters.

ii. Battery Energy Storage Systems: The Battery Energy Storage System will comprise of a series of steel containers which contain the Lithium-ion battery cells in addition to switchgear, inverters and transformers. The facilities required for large scale recycling of Li-ion batteries do not currently exist in the UK although this is likely to change in the future with large -scale deployment of Li-ion batteries in the both the electricity storage and car industries expected over the coming years. In light of this Li-ion batteries are currently sent to recycling facilities in Europe and Asia where recycling rates of circa 90% are achieved with Li-ion batteries. As part of the supply contract the suppliers of Li-ion batteries for Battery Energy Storage Systems arrange the recycling of the Li-ion batteries.

iii. Substation: Substation compounds contain the infrastructure (switchgear, transformers, circuit breakers etc) that allows the safe export/import of electricity to/from the local electricity network. The switchgear that controls the flow of electricity is located within the control rooms and the transformer 'steps' up the voltage of the electricity from the low voltage that is produced by the solar panels to the high voltage required to allow export to the local electricity network. Dismantling of substations is completed by specialist contractors in the UK such as C. Soar and Sons (www.csoarandsons.co.uk), C. K. Beckett (www.ckbeckett.co.uk) and John Robson Metal Ltd (www.johnrobsonltd.co.uk). Recycling rates in excess of 95% are standard in the dismantling of the electrical equipment.

iv. Power stations (Inverters/Transformers): Power stations are located throughout the solar park, and it is here that the low voltage electricity produced by the PV solar panels is converted from DC to AC and the process of stepping up the voltage commences. The inverter converts the electricity from DC to AC. The components of a typical inverter are transistors, capacitors, semi-conductors, inductors and circuit boards. Recycle rates of greater than 95% are standard when recycling inverters. Transformers step up the voltage to the required level and depending on the steps required a series of transformers may be used throughout the solar park. Transformers are made from steel with internal aluminium/copper coils, ceramic bushings, insulation and are typically oil filled. The oil is used to cool down the transformer during operation and also as an insulator and this requires specialist handling when the transformer is being de-commissioned. Transformers are often completely stripped down after use and re-built again to enter the market as a re-furbished transformer.

v. Switchgear: Switchgear is composed of a switches, fuses, relays and circuit breakers which allows the control, protection and isolation of the solar park. Switchgear recycling services are widely available throughout the UK.

vi. Cables: The cables used in solar parks will utilise either copper or aluminium as the conducting material. Cable recycling services are widely available throughout the UK.

vii. Mounting Structure: The mounting structure which is the framework that supports the panels is formed using galvanised steel and/or aluminium both of which are widely recycled in the UK.

1.11 NATIONAL GRID BICKER FEN SUBSTATION EXTENSION WORKS- AIR INSULATED SWITCHGEAR VS GAS INSULATED SWITCHGEAR INFRASTRUCTURE COMPARISON.

1.11.1 Works included in a substation extension will comprise a range of technical components and infrastructure, including switchgear. This apparatus is used for switching, controlling, and protecting the electrical circuits and equipment. Switchgear is used in connection with the generation, transmission, and distribution of electrical energy. For substation extensions with high voltage switchgear either Air Insulated Switchgear (AIS) or Gas Insulated Switchgear (GIS) technology is generally used to transform voltage from low to high or from high to low.

AIR INSULATED SWITCHGEAR (AIS)

1.11.2 Air Insulated Switchgear is located outside open to the atmosphere using atmospheric air as an insulating medium between the generation, transmission, and distribution phases of electrical supply. AIS solutions are often used in extension of substations and where there is sufficient space to accommodate the infrastructure (circuit breakers, transformers, bus bars etc). Air as the dielectric (able to transmit electrical force without conduction i.e. insulating) gas medium is not as effective as other gases causing the need for spacing of infrastructure components required for safe operation, and therefore more outdoor space is needed to accommodate an AIS solution. Higher voltage levels require increased distance of switchgear components for safe operation as the dielectric strength requirement increases. The most commonly used type of substation uses AIS solutions, which represents more than 70% of all substations worldwide.

GAS INSULATED SWITCHGEAR (GIS)

1.11.3 Gas Insulated Switchgear (GIS) contain major conducting structures within a sealed environment, protected from environmental aggressors. All switchgear components are encased in metal modules filled with traditionally sulfur hexafluoride (SF_6) gas with enhanced dielectric characteristics compared to other gases. Modules are connected tightly together in a metal enclosure insulated with SF_6 gas, allowing for minimal space needed between switchgear sections compared to an AIS solution. The metal enclosures also protect the components from deterioration due to exposure to contamination, moisture, and atmospheric air, and allows them to be placed much closer together.

1.11.4 SF_6 is a greenhouse gas with the largest global warming potential (23,500 times more than C~~0~~O$_2$). In the UK, the emerging Draft National Policy Statement for Electricity Networks Infrastructure (EN-5) (March 2023) encourages applicants to avoid the use of SF_6 assets in high voltage switchgear for electricity networks. Where SF_6 reliant infrastructure is required then applicants must explain the alternatives and why these alternatives are technically infeasible in particular with an accounting of the cost differential between the SF_6-reliant assets and the SF_6 alternative.

1.11.5 Alternative SF_6 insulation medium technology is currently being explored for commercial rollout. An example is Green Gas for Grid (g^3) from GE Grid Solutions of a mixture of blended using 3M™ Novec™ 4710 Insulating Gas with a balanced percentage of Carbon Dioxide with a drastically reduced environmental impact[3].

1.11.6 As a consequence, should a GIS solution be available for the project for the Bicker Fen Substation Extension Works, this would be an SF_6 alternative and would not employ SF_6. National Grid Electricity Transmission (NGET) have committed to not using a GIS solution with SF_6 in the Joint Position Statement with National Grid Electricity Transmission (document reference PS-002).

[3] (GE Grid Solutions) -National Grid SF6- free 420Kv Gas-Insulated Line. National Grid