



Development of a Solar Carpark

And associated works at the British Antarctic Survey



**British
Antarctic Survey
Estates**

Authors: Parthena Exizidou, Energy Efficiency & Services Engineer

Editors: John Eager, Head of Estates

Cambridge, 22/08/2018

Contents

Contents	2
Table of Figures	4
Table of Tables	4
1 Introduction	5
1.1 Background.....	5
1.2 Scope	5
1.3 Investment objectives	5
1.4 Existing arrangement.....	6
1.5 Business need	7
1.6 Potential benefits, risks, constraints and dependencies	7
1.7 Critical Success Factors.....	7
1.8 Project Structure and Timeframe	8
1.9 Summary of the Requirement	9
1.10 Site related details & rules	10
1.11 Installation	11
1.12 Site Visit.....	11
1.13 Supervision	11
1.14 Electrical Supply	12
1.15 Water and Electricity	12
1.16 Site Cleanliness	12
2 Project Products Description	12
2.1 Product 1: Development of a Solar Carpark.....	12
2.1.1 Pre – Construction components.....	13
2.1.2 Standard Installation Key components.....	13
2.2 Product 2: Electric Vehicle (EV) charging facilities	16
2.3 Product 3: Carpark outdoor LED lighting system.....	17
2.4 Product 4: Swipe control barriers	17
2.5 Product 5: Secure solar bicycle shed	18
2.6 Product 6: Car park finish surface	18
3 Building control	18
4 Health and Safety	19
4.1 System Signage.....	21
5 Decommissioning plan – End of life considerations.....	21
6 System losses.....	21
7 Monitoring.....	22
8 Electrical design considerations	22

8.1	DC system	22
8.2	DC connectors	23
8.3	DC isolation and circuit protection.....	23
8.4	PV modules	24
8.5	Solar inverter	24
8.6	AC system	25
8.7	AC Isolation and circuit protection.....	25
8.8	Cabling	25
8.9	System earthing and bonding	25
8.10	Metering.....	26
8.11	Lighting and surge protection.....	27
9	Mechanical design considerations	27
9.1	Structure	27
9.2	Carport frame.....	28
9.3	Loading.....	28
9.4	Foundations	28
9.5	Surface carparks.....	29
10	Solar Carpark layout.....	29
10.1	Underground services.....	29
10.2	Component layout.....	29
10.3	Protection from damage.....	30
10.4	Environmental protection of equipment.....	30
10.5	Accessibility	31
10.6	Commissioning	31
11	Operation and Maintenance contract.....	32
12	Warranties.....	32
13	Training	32
14	Feed-in-Tariff scheme	32
	Appendix A: Existing drawing of the car park area	33
	Appendix B: Existing underground services of the car park area.....	34
	Appendix C: Onsite energy consumption profile (HH data), cost and carbon conversion data	35

Table of Figures

Figure 1.1: Map position of the BAS Cambridge site (in blue) and South carpark area (in red).	6
Figure 1.2: Views of the existing carpark area.....	7
Figure 1.3: View of existing bicycle shed.....	7
Figure 1.4: Grass area at the rear of the carpark (in red) available to the Contractor for use.	10
Figure 2.1: Relationship between key components of the solar car park system.	14

Table of Tables

Table 1.1: Phase 1 and Phase 2 list of project products and respective delivery timeframes.	8
Table 2.1: Pre – Construction elements	13
Table 2.2: Specification and associated standards for common EV charge-points.....	16
Table 8.1: Earthing and bonding arrangements.....	26
Table 8.2: Function and typical location of surge protection devices.	27

1 Introduction

BAS Cambridge is the centre for coordinating and managing polar science and operations. Offices, science and engineering laboratories, as well as controlled environment facilities provide the focal point for UK's polar research effort.

BAS Cambridge occupies a site of approximately 2.95 ha and is housed in 7 main buildings with ancillary structures with two parking areas at the northern and southern part of the site. The site has been developed as needs arose from 1976 to 2017 in various construction methodologies depending on the age and use of the building. Areas have been refurbished over the life of buildings. All buildings are mixed use with offices, laboratories and workshops to support all the scientific and logistic activities in the Antarctic. As any mixed used scientific research site, Cambridge headquarters comprise specialised facilities for the scientific staff, mechanical and electrical areas and the main specialist areas for science.

1.1 Background

BAS Cambridge site achieved a significant decrease in total energy consumption in the last 7 years, which resulted in a decrease in carbon emissions by 29%. This important decrease is the result of a number of energy upgrade projects that have been planned and executed during this period. Insulation improvements, boilers' replacement, cold room refurbishment and LED lights are the major projects that had a significant effect on improving BAS Cambridge energy performance.

Following the BAS Energy Strategy, it is a high priority to reduce further the organisation's carbon footprint whilst providing high quality living and working conditions. In addition, under the BAS Environmental Strategy, BAS is committed to continually improve the environmental performance through the adoption of energy efficient practices and pursuit of innovative solutions.

The Development of a Solar Carpark and Associated Works project is considered an important project for BAS that will assist in achieving the energy and environmental targets and increase the renewable energy generation in the BAS energy mix.

1.2 Scope

The BAS Cambridge site is in need of a strategic investment in order to bring forward a spend to save initiative that would enable BAS to reduce carbon emissions by the use of renewable energy systems, would provide for charging points for electrical vehicles visiting the site, would enhance car park for security, provide a new car park surface, and enable a secure bike shed to be provided within the car park perimeter.

1.3 Investment objectives

The purpose of the investment is to create Solar Panel Ports over the existing car bays across the length of the south car park. These will provide electricity generation for the site, while at the same time providing charging points for electric vehicles and cover for parked vehicles, thereby reducing solar gain in parked vehicles.

Additionally, there will be a height restriction and access/exit control to the car park via swipe controlled barriers. This will alleviate an enduring security issue around use of car parking by adjacent buildings and a safety issue around exiting the car park incorrectly in the one way system.

Finally, as part of the initiative, cage type enclosure with a solar canopy/roof around the bicycle park area will be fitted, thereby improving security for users, further encouraging bike use and

increasing the generated electricity from solar PVs on site. The new bicycle shed will double the space available for bicycle storage from 100 to 200 by using a two tier rack system.

The initiative fits in with the BAS environmental objectives: reducing carbon footprint; and encouraging alternative travel methods (EV and bike). In general, the investment will also address security issues around the car park (non-BAS users) and safety issues (exiting incorrectly via one-way system).

In addition to the environmental, security, staff welfare and carbon reduction benefits this project provides necessary maintenance to the BAS staff car park.

1.4 Existing arrangement

Currently the south car park (Figure 1.1) is open bay layout (4 double bays and 2 single bays) without controlled access to and from the facility. The bicycle shed towards the western end of the car park is open sided with U posts for securing bikes.



Figure 1.1: Map position of the BAS Cambridge site (in blue) and South carpark area (in red).



Figure 1.2: Views of the existing carpark area.



Figure 1.3: View of existing bicycle shed.

The existing car park (Figure 1.2) currently provides 120 car park spaces (24 per double bay) and the bicycle shed space for 100 bicycles (Figure 1.3). The entire car park covers an area of around 3000m². More information on distances can be found in the original drawing in Appendix A: Existing drawing of the car park area.

1.5 Business need

BAS currently has no renewable energy generated and used on site and does not have any charging facilities for EV transport. In addition the bicycle port is open sided without secure access. Thefts of bikes have been reported and there is a need to provide a more secure system for bike users. Last, the car park surface is degrading and there is a need for replacement.

1.6 Potential benefits, risks, constraints and dependencies

The main benefits to BAS will be a reduction in energy consumption, the provision of EV charging points, enhanced security for cyclists and a new car park surface. There is however a significant additional benefit in terms of the messaging around the investment in an environmental initiative that provides related improvements to the amenity of the BAS estate.

1.7 Critical Success Factors

The critical success factors for the project are as follows:

- Reduction in the BAS carbon footprint by at least 45 tonnes of CO₂e pa (from PV electricity generation by the solar carports and solar bicycle shed canopy)
- Energy cost savings of at least £15k pa on current consumption costs from grid electricity and carbon emissions related costs (ex CRC costs)
- Feed in tariff benefits for BAS for the solar carports
- Provision of fast EV charging points for a minimum of two vehicles
- Secure access-controlled bike shed with a solar roof
- Improved low maintenance car park surface

Note: It is important to note that the Feed-in-Tariff (FiT) scheme which is a Government scheme designed to promote the uptake of renewable and low-carbon electricity generation is coming to an end during April 2019. It is therefore crucial that all necessary actions are taken by the contractor for on time delivery for BAS to be able to secure the FiT benefits for the electricity generated by the 4 double bays of the solar carport.

The BAS Cambridge site 2017 electricity consumption was 1,795,097 kWh. The Centre is in operation 24 hours a day, 365 days a year. Half Hourly electricity consumption data can be found in Appendix C: Onsite energy consumption profile (HH data).

The Contractor should calculate energy, carbon and cost savings based on the information provided in the Appendix C: Onsite energy consumption profile (HH data), cost and carbon conversion data” for a 25 year lifecycle of project and based on Cambridge sunshine datum point.

1.8 Project Structure and Timeframe

The project will be divided into two phases. A summary of works and respective timeframe under each phase can be seen in Table 1.1.

Table 1.1: Phase 1 and Phase 2 list of project products and respective delivery timeframes.

Phase	List of Project Products	Delivery Timeframe
1	1. Solar carpark (at 4 double bays) at the south car park area (design, supply, install, test and commission) 2. Fast EV charging facilities for at least 2 vehicles 3. Carpark outdoor LED lights and controls 4. Swipe control barriers (entrance and exit)	December 2018 to March 2019
2	5. Secure bicycle shed with solar roof 6. Car park finish surface	April 2019 up to March 2020

All works for Phase 1 must be complete, commissioned and handed over (with O&M documentation) by **31st March 2019**. **In order to achieve the deadline for Phase 1, installation should start the first week of January 2019 the latest.**

Note: For minimising disruption and increasing delivery speed to ensure delivery dates, night as well as weekend working is also suggested where appropriate for all works under this specification. Normal working pattern for the BAS Cambridge site is 08:00 – 17:30, Monday to Friday.

Note: The Contractor shall provide input to this tender event for both Phase 1 and Phase 2.

Note: Please note that procedures for granting planning permission from Cambridge City Council, DNO and Cambridge University are in place and ongoing and approval is yet to be granted.

1.9 Summary of the Requirement

The Contractor shall design, supply, install, test and commission the installations as detailed within this specification, employing skilled personnel and specialist contractors as necessary to achieve the standards described.

During Phase 1 and until the end of March 2019, the Contractor shall design, supply, install, test and commission the solar carports for the 4 double bays of the existing carpark area, the Electric Vehicle charging points, the exterior lighting system and controls for the carpark and the swipe control barriers at the entrance and exit of the carpark.

During Phase 1, the Contractor shall be responsible for securing the Feed-in-Tariff (FIT) benefits for the solar carpark including preparing and managing all applications necessary for achieving this before the FIT deadline.

During Phase 2, the Contractor remove the current bicycle shed and shall design, supply, install, test and commission a new secure bicycle shed (swipe control) with a solar roof/canopy. In addition, during Phase 2, the contractor will remove the existing carpark surface and provide a new one.

The Contractor is also responsible for the following:

- Structural calculations and ground surveys
- Construction design management / Risk Assessment Method Statement
- Electrical design and schematics
- Mechanical design, working documents and details
- MCS / Ofgem certificate
- DNO Application – G59
- DC switchgear, cables and connectors
- AC switchgear, cables and connectors
- System connection
- G59 protection
- All relevant labelling
- Electricity Metering (generation, export, EV charging points use)
- Basic remote monitoring system (Emig half hourly)
- Testing and Commissioning
- Access / Lifting equipment
- Lightning protection system
- Installation
- Waterproofing of cable entry points
- On site storage/welfare
- Site waste clearance waste disposal including old lighting system
- Operator training and Operation & Maintenance Manual
- Link to fire alarm
- Generator interlock

The Contractor should have a proven track record of delivering installations similar to the needs of the current project and should have distinctive quality of installed work.

Since the works are going to take place at the parking area of the headquarters of BAS, the projects entails disruption related to the reduction of the number of available carpark spaces and the noise of construction works. The Contractor should provide a plan in order to limit the impact of disruption by working at only part of the carpark area at a time, allowing the remaining area to be operational.

Desirable Contractor accreditations:

- ISO 14001, ISO 18001, ISO 9001
- Achilles
- MCS
- NIC-EIC
- CHAS
- Construction line
- Safe contractor
- Renewable Energy Consumer Code Certificate
- Investors in the Environment

A detailed Project Product Description is provided at Chapter 2 of this specification.

1.10 Site related details & rules

The contractor is allowed to use the grass area at the rear of the carpark for site accommodation and storage (Figure 1.4).



Figure 1.4: Grass area at the rear of the carpark (in red) available to the Contractor for use.

The Contractor shall provide their own welfare and accommodation facilities.

All Contractor staff should be wearing BAS issued security budes.

Contractor is to make provisions for safe access and regress for vehicles, pedestrians and cyclists to the bicycle shed and to the operational part of the carpark throughout the works duration.

1.11 Installation

A detailed programme of works is to be drawn up for the complete installation as required under a NEC3 contract. A provision is to be made for any scaffolding/protection requirements.

This programme is to be agreed with the client (BAS) before commencement of the works.

Time and carpark space is limited so once approval is achieved, the installer/tenderer is to achieve delivery in an orderly and just-in time manner, without affecting the agreed programme.

Allowance is to be made to:

- Carry out a site inspection and surveys
- Allow for any testing requirements for system prior to installation
- Allow for phased installation to minimize disruption and keep part of the car park area and bicycle park area operational.

Design and installation is to be carried out in strict accordance MCS guidelines and current CDM regulations.

1.12 Site Tour

The dates available to attend a site tour can be found within FM18156 Development of a Solar Carpark and Associated Works Request for Proposal Section 3 – Timescales.

If you wish to request a site tour, please ensure that this is done via the messaging function in the eSourcing portal. Once your proposed date and time has been confirmed with the client we will confirm this back to you.

During the site tour the host will be unable to answer ANY questions. Should you have further clarification questions from the tour these will need to be taken away and then formally submitted through the eSourcing portal.

The Contractor shall include in their tender for all costs necessary to take account of the above and arrange for delivery of their materials so that no congestion occurs and shall include for all additional handling and transporting due to site conditions.

No claim shall be allowed in the settlement of the account in respect of anything mentioned in this item, neither will the lack of knowledge or ignorance of conditions be accepted as justifying such a claim.

1.13 Supervision

The Services Contractor shall maintain site supervision which shall be one of the following:

1. A site manager or equivalent permanently based on site
2. A working chargehand or foreperson

The supervisor shall:

1. Be present on site whenever work is in progress by or on behalf of the Contractor.
2. Be appropriately qualified and have previous experience for the class of work specified.
3. Be approved by the Contract Administrator
4. Be a responsible representative to whom site working instructions shall be transmitted.

The working supervisor may be changed only after permission to do so has been granted by the Contract Administrator, this shall occur in exceptional circumstances only.

1.14 Electrical Supply

The characteristics of the available electric supply have been determined as follows:-

1. Phase voltage – 11,000V / 400 volts
2. Frequency – 50Hz
3. Fault level – TBC by UKPN
4. Earthing arrangements – TN-S or TN-C-S

The above shall be assumed for Tender purposes only, actual supply details shall be verified on site prior to commencing working drawings / placing orders.

All equipment, including motors and starters shall be provided to suit the voltages and phases and shall be verified before final orders for materials are placed.

As part of their co-ordination duties, the Contractors shall exchange relevant information from their specifications that relate to equipment being procured prior to placing any orders (for example access control systems for barriers, bicycle shed).

1.15 Water and Electricity

Water and electricity consumed during the construction of the works shall be provided by the Employer free of charge.

1.16 Site Cleanliness

The Services Contractor shall allow for cleaning up and carting away all his own rubbish as it accumulates during the progress of the works, including that of his Sub-Contractors, and on completion he is to clear up and cart away all superfluous materials, clean down external faces of buildings affected by the works, scrub pavings and floors, clean out gullies and gutters etc., clean glass inside and out, remove all spots, splashes and stains and leave the works and all parts of the premises affected by them clean and in good order to the entire satisfaction of the Contract Administrator.

At the end of each working day all his own rubbish shall be cleared away.

The Services Contractor shall ensure that all rubbish, waste and offcuts etc. are cleared away in accordance with the Main Contractors waste management plan.

2 Project Products Description

2.1 Product 1: Development of a Solar Carpark

The Contractor will design, supply, install and commission a Solar Carpark at the south car park area of BAS Cambridge that will be connected to the distribution network. A solar car park is a parking facility consisting of multiple solar carports - shelter for one or more cars that incorporates solar photovoltaic (PV) modules. The solar canopies are going to cover the four (4) double bays which are currently uncovered (Figure 1.2). The single bays, one at the top of the existing carpark and one at the bottom are going to remain as is.

The function of the Solar Carpark is the generation of low carbon renewable energy that will be used with the following priorities:

1. On site by EV charge points
2. On site by any connected buildings
3. Sold off site (to the grid)

2.1.1 Pre – Construction components

Pre-construction components comprise the following elements of Table 2.1.

Table 2.1: Pre – Construction elements

Pre – construction elements
M&E design
Civils design
DNO (G59) application
Structural design and support (calculations and ground surveys)
Existing services survey
Topographical survey
Geotechnical survey
Earthing study
Protection study
Link to fire alarm system
Generator interlock
Metering and connection to current meeting system
Ofgem registration
Export control

2.1.2 Standard Installation Key components

The Solar PV system for the carpark will consist of three major components; Solar Panels, Inverters and the Mounting System which will secure the solar panels to the ground. Additional items for the Solar PV system include cables, cable containment and switchgear.

System configuration can be seen in Figure 2.1.

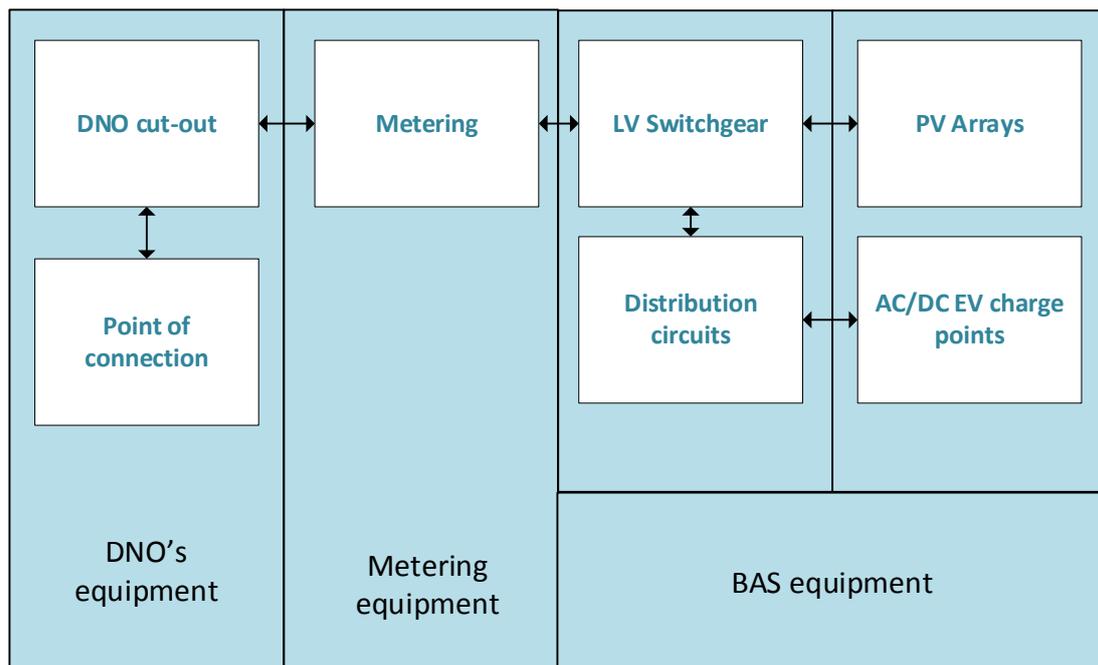


Figure 2.1: Relationship between key components of the solar car park system.

Component 1: Solar Panels

The Contractor should propose specific type of solar panels based on the following parameters:

- Quality criteria, including Tier 1 products
- Panel efficiency
- Cloudy days and low light performance
- Product performance (power output) after lifespan
- Manufacturer reliability (solid reputation, test results, warranty, service) ensuring product continuity to backup any warranty issues

It is important that the Contactor shall receive specific recommendations from the Manufacturer of the panels for earthing arrangements for the DC system to reduce or reverse the effects of the PID. This is mainly because of particular types of PV modules can be prone to potential induced degradation (PID), a voltage potential between the PV module and the ground that can reduce PV module performance. The effects of the PID can worsen in PV systems that experience high levels of humidity, temperature and soiling.

The PV module casing and pre-fitted connector cables should be double insulated (safety class II) as recommended by BS 7671 for any system where the string voltage ($V_{oc_{STC}}$) exceeds $120V_{dc}$ in order to minimise the risk of fire and electric shock.

Using polarised connectors prevents incorrect polarity connections in the system. It is important that polarised connectors from different manufacturers are not coupled together and all connectors are suitably rated to ensure safe operation of the system.

A suitable bypass diode configuration should be selected with respect to the carport array layout (e.g. PV modules in landscape or portrait) and with respect to any potential shading to reduce the effect of shade on the output of a module.

Any PV module selected should be certificated to 'BS EN 61730. Photovoltaic (PV) Module Safety Qualification'¹. Any structural glazing materials used in the construction of PV modules (as a superstrate or substrate) must also comply with the standard for safety glazing in 'ANSI Z97.1-93. American National Standard for Safety Glazing Materials Used in Buildings'. If further safety testing of glazing is needed, reference to the BS 5516 Series 'Patent Glazing and Sloping Glazing for Buildings'² should be made. In addition, further certification of PV modules under the Microgeneration Certification Scheme (MCS) product standard MCS 005 is welcomed.

Component 2: Inverters

Solar inverters should optimise output from the PV modules by using maximum-power point tracking of the string voltage.

Performance should be optimised delivering more energy for the system lifetime by controlling the PV system at module level. This way differences related to individual set of characteristics of each panel is accommodated. Monitoring each panel individually is essential in order to

¹ Photovoltaic (PV) Module Safety Specification BS EN 61730 – 1:2007 + A11:2014, British Standards Institute (BSI, 2015)

² BS 5516-2 Patent glazing and sloping glazing for buildings code of practice for sloping glazing, (BSI, 2004)

detect errors by the monitoring system. The inverters system should minimise the risk of reduced output due to shading or different orientation.

All panel level DC electricity should be kept next to the panels. Only when the inverters send a control signal should the system operate. In the event of a fire, or grid failure the fire brigade should be reassured that only the panels are 'live'. Automatic shutdown feature of the system in the event of a fire alarm triggering and not just waiting for the main electrical isolator to be shut off should be included. All communication within the system should be performed through existing DC cabling which is the most reliable method of transmitting data.

Essential inverter beneficial elements required:

- Automatic shutdown of each module for maximum safety
- Wired communication, not wireless for better reliability
- Incorporates all communication and system control in optimisers and inverter
- Safe DC
- Individual module performance visibility
- Automatic alerts on system issues text/email
- Easy access online monitoring via computer, smartphone or tablet
- Centralised single point contact for onsite support and troubleshooting

The Contractor should advise on the available options for positioning location for inverters and electrical connections, taking into account the need for clear access to the car parking space. Safety and security of inverters should be considered when selecting technology options.

Inverters should be open protocol (BacNet or something similar) to allow potential connection to building management system.

Component 3: Mounting System

The PV glazing system should be well executed as such to reduce the use of materials and project costs. The system should also ensure water tightness, structural strength and fire resistance.

The solar carport roof structure will provide the mounting system for a specified PV module. Confirmation is necessary to be provided by the PV module manufacturer that they approve of the mounting system design and method of securing the PV modules in place.

For the integrated PV glazing systems, the mounting system should be directing rain water, securing the PV modules and providing fire resistance.

The design of the solar carport should include wind loading and wind induced effects (correct pressure coefficients chosen), self-weight of the PV module and mounting frame, snow loads, and loads imposed during construction³. In the absence of existing standards, certification of a solar carport mounting system can be achieved under MCS product standard, MCS 012, demonstrating resistance to external fire spread, weather tightness and wind uplift resistance⁴.

Drainage

Adequate surface water drainage measures should be incorporated in the design. The Flood and Water Management Act (2010) requires all new developments to incorporate sustainable

³ Analysis and guidance on calculating applied pressure from wind and subsequent wind loads on roof-mounted PV and solar thermal systems. Wind Loads on roof-mounted photovoltaic and solar thermal systems, BRE National Solar Centre, (Blackmore, 2014).

⁴ MCS 012 Product Certification Scheme Requirements: Pitched Roof Installation Kits, Microgeneration Certification Scheme, (MCS, 2018).

urban drainage systems⁵, solar car parks must have adequate runoff management strategies to meet these requirements. When designing drainage layouts and calculating effective roof area to determine rainwater runoff calculations the total surface area of a solar carport should be considered as the total roof area.

Car parking drainage is specified in Building Regulation Part H: Drainage and waste disposal. The emphasis of these regulations is on structural integrity and rainwater disposal. As such, the runoff management strategy for the carport must be able to dispose of peak rainfall to prevent increased loading on the roof. The Contractor should advise on best system to achieve this.

Rainwater drainage pipes should discharge into the existing below ground drainage of the car park area given that it has sufficient drainage capacity, as per original design requirement.

2.2 Product 2: Electric Vehicle (EV) charging facilities

BAS, through the current project product, aims to provide BAS employees and visitors with the infrastructure of EV charging points to accommodate the changes in mobility modes. The development of the solar car park plays an important role in this facilitation.

The Automated Electric Vehicles Act⁶, which passed through parliament on the 19th of July 2018, is set to require all new charging infrastructure to be able to communicate and respond to requests from a third party. Under the new law, the Contractor should ensure charge points are compatible with all EVs and standardise payment systems for charging and setting standards for reliability.

The Alternative Fuels Infrastructure Regulations⁷ which came into effect in 2017, also places requirements on EV infrastructure, such as ad-hoc access and minimum connector standards. Smart EV charge-points on multifunctional solar car parks provide additional benefits, such as being able to optimise operating regimes in line with solar electricity generation, programming of usage and predictive maintenance.

Any EV charge-point and associated equipment must comply with the current product standards (BS EN 61851 series 'Electric vehicle conductive charging system', BS EN 62893 series 'Charging cables for electric vehicles for rated voltages up to and including 0,6/1 kV' and BS EN 62196 series 'Plugs, socket-outlets, vehicle connectors and vehicle inlets').

Table 2.1 presents the standards and specifications associated with EV charging equipment for both connections to infrastructure (electricity source) and vehicle. A minimum of Type 2 sockets and connectors for AC charging and combined charging system (CCS) for DC charging should be provided as specified by the relevant regulations. Intelligent metering systems that allow any person to recharge an electric vehicle without entering into a pre-existing contract is also required.

Table 2.2: Specification and associated standards for common EV charge-points

Infrastructure side	
Connector type	Industrial plug and socket
Associated standard	BS EN 60309-2
Charging mode	2 (AC)
Max power (kW) and phase	Single – 7.4 Three - 22

⁵ Sustainable Urban Drainage Systems design guidance, Local Flood Authorities of South East England, (Aecom, 2013).

⁶ <https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html>

⁷ <https://www.gov.uk/guidance/regulations-alternative-fuels-infrastructure>

Vehicle side	
Connector category	Specialist EV
Associated standard	BS EN 62196-2 Type 2
Charging mode	3 (AC)
Maximum power (kW) and phase	Single – 7.4 Three - 22

The EV charge-points are intended to be accessible by BAS staff and visitors and therefore they are expected to be on a network for authorised electronic key holders, where individuals register to use the facility and make payments, or via smart phone apps.

The current project product will comprise fast charging points to accommodate at least two vehicles.

2.3 Product 3: Carpark outdoor LED lighting system

Lighting of the solar carpark must conform to lighting levels for outdoor car parks designated by BS 5489-1:2013 'Code of practice for the design of road lighting. Lighting of roads and public amenity areas.' A minimum horizontal illuminance should be provisioned based on existing type and use of the carpark⁸. Lighting infrastructure should be placed in areas that maximise bay illumination without creating obstructions⁹ as well as limiting spill and light trespass into adjacent areas¹⁰.

Further supplementary standards to aid with the solar car park planning in the design of the lighting system include; BS EN 12464-2: 2014 'Lighting of work places. Outdoor work places'¹¹, BS EN 13201-2: 2015 'Road Lighting. Performance requirements'¹² and BS 5266-1:2016 'Emergency lighting. Code of practice for the emergency lighting of premises'¹³.

The Contractor should design, supply and install the necessary lighting system with LED according to the aforementioned requirements.

The exterior lighting system will be controlled by a combination of photocells and timers in order to allow for optimal light levels and limit night operation.

Lights should be provided by Thorn Lighting and all electrical switch gear should be Schneider Electric for matching the remainder of the site lighting systems.

2.4 Product 4: Swipe control barriers

The Contractor will design and install a height restriction (removable) swipe control access barrier at the entrance and exit of the carpark area.

G4S as BAS nominated subcontractor and should be used for access control systems to match the remainder of the site. In addition, Strand Automation should be used for the barriers and control panel.

⁸ Code of Practice for Design of Road Lighting, BS 5489-1:2013, British Standards Institute, (BSI, 2013).

⁹ How to guide: Lighting Car Parks, DW Windsor, (DW Windsor, 2012).

¹⁰ Guidance note for the reduction of obtrusive light, Institute of Lighting Engineers, (ILE, 2005).

¹¹ EN 12464-2: 2007 Lighting of work places, British Standards Institute, (BSI, 2007).

¹² EN 13201-2: 2015 Road Lighting Performance requirements, British Standards Institute, (BSI, 2015).

¹³ BS 5266-1:2016 Emergency Lighting of Premises, British Standards Institute, (BSI, 2016).

2.5 Product 5: Secure solar bicycle shed

A secured access-controlled bicycle shed should be installed to include a solar canopy/roof. For the access control system G4S will be used to match the remainder of the access systems of the site.

The enclosure of the bicycle shed could be mesh type and provide apart from the access controlled entrance, an emergency exit.

The design of the bicycle shed should provide double capacity of the bicycle park spaces compared to existing, by using a two tier rack structure.

The racks should be manufactured from tough steel. Steel framework should be robust welded construction, hot dip galvanised to BS EN ISO 1461.

The bicycle shed replacement / upgrade will include the following:

- Demolish / dispose of existing bike shed
- Installation of new secure bike shed including an access controlled gate
- Shed to include a roof with structural capacity for solar panel installation (similar type to the solar canopy of the car park)
- Storage for 200 bikes in a two tier system
- External and internal motion activated lighting

The new bicycle shed shall also include a public bicycle maintenance stand with integrated pump in order to provide cyclists with a stable workstation to tune their bike and make repairs. A wheel chock should be also included.

2.6 Product 6: Car park finish surface

Car park finish surface should provide a new finish surface at the 3200m² of the existing park area, maintaining the existing layout of the car park in order to provide 120 parking spaces.

- Supply and machine lay dense bitumen macadam wearing course to required thickness using 10mm coated chippings to car-park and road way
- Power roll as required
- Machine sweep all roadways / car park as required
- Supply and install Hot thermoplastic linings to all areas as required
- All waste removed from site

3 Building control

The installation of a multifunctional solar car park is notifiable under the relevant sections of the Building Regulations¹⁴.

Carports are classified as buildings and must comply with the Building Regulations¹⁵, in particular the following sections from Schedule 1:

Part A: Structure - This identifies the relevant legislation relating to the basis of structural design and loading, construction materials and workmanship, stability and foundations. This is particularly relevant for the solar carport frame and foundations.

¹⁴ Building Regulations 2010, as amended for England & Wales or Building (Scotland) Regulations 2004, as amended for Scotland.

¹⁵ <http://www.legislation.gov.uk/uksi/2010/2214/schedule/1/made>

Part B: Fire Safety – Volume 2 covers fire safety matters within and around non-domestic buildings, including means of warning and escape, internal and external spread of fire, access and facilities for fire services.

Part C: Resistance to contaminants and moisture – Details the requirements for site preparation and ground conditions for construction projects. This is particularly relevant for any car parks located in a flood risk area, on contaminated land or in areas where there is a build-up of underground gases such as methane and radon.

Part H: Drainage and waste disposal – Covers the requirements for rainwater drainage, including the specification for guttering, surface water draining and oil separators. This is particularly relevant for car parks due to the potential of pollution from cars entering the local watercourses.

Part K: Protection from falling, collision and impact – This document details the requirements to provide protection measures for any users or activities in the car park. This is particularly relevant for any working at heights activities on or near the carports, such as window or PV cleaning.

Part M: Access to and use of buildings – Volume 2 covers access to non-domestic buildings from onsite car parks. This document provides specific advice with regards to inclusive design of car parks and due consideration should be given that a solar carport structure and layout can accommodate these requirements.

Part P: Electrical safety – All though this part of the Building Regulations refers to dwellings, it does apply to any electrical circuits connected to mixed-use developments. Certification of new electrical installations is still a requirement under BS 7671.

Carports are listed as exempt from Part L: Conservation of fuel and power¹⁶.

Approved Documents¹⁷ are available which describe means to meet the requirements of the relevant Parts of the Building Regulations. Please note that these documents are not the Building Regulations, although they reference the relevant sections.

4 Health and Safety

To uphold stringent health and safety during the construction phase of a solar car park, all health, safety and welfare provisions for persons at work must be provided¹⁸ as well as upholding the responsibilities ensconced within the Construction Design and Management Regulations 2015 (CDM)¹⁹. CDM covers civil and engineering works of any scale including construction, retrofitting, repair and decommissioning stages, applying to all life cycle phases of a solar car park.

Under CDM consideration must be given to the planning and co-ordination of maintenance and repair of all components of a multifunctional solar car park. Adequate site security should

¹⁶ Approved Document L2B: conservation of fuel and power in existing building other than dwellings, 2010 edition (incorporating 2010, 2011, 2013 and 2016 amendments).

¹⁷ https://www.planningportal.co.uk/info/200135/approved_documents

¹⁸ Health and Safety at Work Act 1974 (TSO, 1974) and Health and Safety at Work Order 1978, Statutory Instrument 1978 no. 1039 (N.I. 9), (TSO, 1978)

¹⁹ Construction site requirements and project management in relation to health and safety duties and roles. Construction (Design and Management) Regulations, Statutory Instrument 2015 No. 51, (TSO, 2015)

be provided to guard against theft and limit the danger of unauthorised persons causing self-inflicted injury.

CDM regulations documentation, specific risk assessments etc. shall be provided as follows:

1. In electronic format and the Services Contractor shall agree number of paper copies to be issued for comment with the Principal Contractor/Principle engineer, for tender purposes assume 4.
2. Manufacture / installation works shall not commence until the documentation has been returned without any outstanding comments from the Principle Contractor/Principle Designer, all comments shall be addressed prior to final copy being issued for inclusion in the Health and Safety File.

Installation and maintenance of the PV modules must be carried out in accordance with the Work at Height Regulations (2005)²⁰ and the guidelines presented in Health and Safety in Roof Work (2012)²¹. Ensuring that only designated competent persons²² carry out removals and replacement of damaged PV modules. Risks and hazards posed by fracture of the PV modules themselves mean that a response plan must be put in place to ensure that any breakage is swiftly communicated to, and handled by, the solar car park operator's competent person.

Methods of installation and maintenance of solar carport systems that negate the requirement to work at height should be considered. Further guidance on glazing at height as well as risk assessment examples and mitigation measures are provided in BRE publication BR471: Sloping glazing, Understanding the risks²³.

Monitoring for signs of corrosion and/or deformation of steel members should be conducted to ensure that the structural integrity of solar carports are maintained. The design working life, accommodating for issues such as corrosion, is to be designed in accordance with BS EN 1990 and therefore the timeline of use for structural members including anticipated maintenance²⁴ can be developed. Using this method alongside monitoring for unexpected structural deformations such as those potentially resulting from heavy vehicular impact enables the solar carport structure to maintain integrity and subsequently the health and safety of users.

Consideration should be given to the health and safety risks arising from electrical connections and components²⁵. Safe working practices²⁶ should be defined and observed with the electrical system of the solar carport. Particular attention should be taken of the risks posed by the DC side of the system. Each solar car park system should also have a bespoke maintenance and monitoring plan. During operation, health and safety is to be upheld through constant monitoring of correct system functionality and maintenance of safety and protective equipment.

Fire risk and prevention should be considered at all stages of the development of a multifunctional solar car park. Under law a nominated person will be responsible for the fire safety of the car park²⁷. It is recommended that a fire risk assessment is completed by a

²⁰ Working at Height Regulations 2005. Statutory instrument 2005 No. 735 (HSE, 2005)

²¹ Health and Safety in Roof work (HSE, 2012)

²² Technical Note 66 - Safety and Fragility of Glazed Roofing: guidance on specification (Centre for Window and Cladding Technology, 2012)

²³ BR471 Sloping glazing: Understanding the risks, BRE, (Kelly and Garvin, 2004)

²⁴ Designers Guide to Eurocode: Basis of Structural Design, ICE Publishing, (Gulvanessian et al., 2012)

²⁵ Electrical Safety, Quality and Continuity Regulations 2002

²⁶ HSG85 3rd edition. Electricity at work. Safe working practices (HSE, 2013)

²⁷ Regulation Reform (Fire Safety) Order 2005

competent person/organisation when designing a multifunctional solar car park system and reviewed at installation and commissioning stages. Consideration should be given to the location of the system components with respect to any existing fire escape routes, mustering points etc. that may already be located in the car parking area. Any walk-in enclosures should feature hard-wired fire detection systems.

4.1 System Signage

System signage is critically important for informing users, maintenance engineers and emergency services of the system, its operation and any potential hazards it may introduce. Drawing attention to the presence of a hazard or potential danger is a minimum requirement for mitigation of most health and safety risks associated with multifunctional solar car parks. Signage should be appropriate, effective and well maintained²⁸.

Signs warning of multiple electrical sources should be installed at the point of connection with the distribution network, any distribution boards or switchgear that are connected to the solar carport system (directly or indirectly) and at the inverter. Electrical schematics showing how the system is connected and the location of all key components and isolation devices should also be durably affixed at these locations. In addition labels should be affixed adjacent to each EV charging circuit RCD and any isolation devices explaining their operation.

It is recommended that DC cable runs are labelled every 5 – 10m.

Guidance on appropriate signage for each part of the multifunctional system can be found in the corresponding IET Code of Practice Guides²⁹.

5 Decommissioning plan – End of life considerations

The project should be designed with decommissioning and end of life responsibilities, in accordance with the good practice required by the CDM regulations. This should not only include the practicalities of dismantling and removing the infrastructure of the multifunctional solar car park systems (such as foundations) but also detail how the waste will be dealt with, any associated environmental impacts and what restoration work is required/ will be completed.

The decommissioning plan should clearly state how the applicable waste regulations³⁰ will be met, identify any reusable or recyclable components of the system and how these will be managed (i.e. through compliant waste management services such as PV Cycle³¹), and detail how other waste will be segregated and disposed of.

6 System losses

The system design, component selection and system maintenance plan should take into account a number of system losses involved in the functions and processes of the multifunctional solar car park system in order to mitigate their impact. System losses can be categorised as follows:

²⁸ The Health and Safety (Signs and Signals) Regulations 1996

²⁹ Code of Practice for Grid Connected Solar Photovoltaic Systems (IET, 2015), Code of Practice for Electrical Energy Storage Systems (IET, 2017), Code of Practice for Electric Vehicle Charging Equipment Installation (IET, 2015)

³⁰ Such as Waste Electrical and Electronic Equipment Regulations 2013 and Waste Batteries and Accumulators Regulations 2009

³¹ <http://www.pvcycle.org/>

- Solar conversion losses (solar cell temperature, PV module quality, PV module mismatch, soiling, shading, internal wiring losses)
- DC/AC Conversion losses (inverter efficiencies, MPPT losses⁵⁰, EV charging efficiencies) – Distribution losses (resistive connections, I²R losses⁵¹)
- Auxiliary system losses (power consumption for ventilation/ monitoring/ control systems, inverter power consumption at night)
- Downtime losses (grid conditions, faults, component failure, maintenance, restricted distribution network connection) Current guidance³² on voltage drop in conductors should be observed i.e. maximum 5% for AC distribution circuits, 3% for DC circuits, 1% for AC inverter circuits and 1% for solar circuits.

7 Monitoring

Appropriate monitoring and control systems should be selected and installed for the safe operation of the whole system.

A number of the components installed will have their own inbuilt monitoring systems, such as the inverters, DC combiner boxes, battery management system and EV charge-points.

8 Electrical design considerations

There are a number of safety legislation, standards and considerations that should be factored in to the system design. All components should be designed, manufactured and tested in accordance with relevant safety standards (see Appendix A for more details). The electrical system as a whole will need to comply with the following regulations;

- Electricity at Work Regulation 1989
- Electrical Safety, Quality and Continuity Regulations 2002
- Electrical Equipment (Safety) Regulations 2016
- Electromagnetic Compatibility Regulations 2016
- Control of Electromagnetic Fields at Work Regulations 2016 – BS 7671 (IET Wiring Regulations)
- ENA Engineering Recommendations G59, G83, G100, G98 or G99 (as appropriate)

8.1 DC system

Unlike other DC circuits, PV arrays do not provide a fixed voltage and/ or current output, as this varies with the solar irradiance and operating temperature the PV modules are exposed to. It is therefore important to ensure that other components within the system are able to tolerate the maximum voltage (open-circuit voltage, V_{oc}) and current (short-circuit current, I_{sc}) that the PV modules, strings, and arrays can produce.

For PV circuits it is recommended that the minimum rating for all DC components should be established, using the crystalline PV module characteristics under standard test conditions (stc)³³, as $V_{oc} (stc) \times 1.15$ and $I_{sc} (stc) \times 1.25$.

For non-crystalline PV modules the V_{oc} and I_{sc} should be calculated from manufacturer's data as the maximum value under the conditions of irradiance: 1,250 W/m², temperature range: -15°C to 80°C, including any increased electrical rating expected during the 'soaking in period'.

³² BS 7671:2008+A3: 2015 Requirements for Electrical Installations - IET Wiring Regulations (17th Edition) and Guide to the Installation of Photovoltaic Systems (MCS, 2012)

³³ standard test conditions for Europe are irradiance: 1000 W/m², temperature: 25°C, air mass: 1.5

As PV modules generate electricity whenever exposed to daylight they should always be considered to be live, as should all connected DC components. Particular care needs to be taken to mitigate electrical shock and fire hazards during the installation, operation and maintenance of systems.

8.2 DC connectors

DC solar connectors should be class II rated and certified in accordance with BS EN 50521 'Connectors for photovoltaic systems – safety requirements and tests'.

To ensure safe functionality, only DC solar connectors of the same type and from the same manufacturer should be connected together and assembled as per the manufacturer's specification. This is to avoid fire risk from poorly fitted, specified or mismatched DC solar connectors³⁴.

All live DC connections should be protected and located out of the reach of the general public.

All DC connections should be periodically checked to confirm that they are tight and secure (referring to manufacturer for torque setting).

8.3 DC isolation and circuit protection

PV cells are current-limiting devices and therefore the short-circuit current of a PV module; string; or array is not much bigger than the operational current. DC isolation and circuit protection requires careful selection.

The selection and specification of DC safety equipment depends on the inverter configuration and earthing arrangements. Current discrete RCD technology is not suitable for the protection of DC circuits. All system components should be specified in line with BS 7671.

DC isolators are a safety-critical component. The poor design, selection and installation of DC isolators has been the cause of a number of system failures and on occasion leading to other more serious incidents, such as fire. Suitable methods should be used to isolate the system at; PV string, PV sub-array, PV array and battery level. Not all methods are suitable to break DC circuits under load, i.e. DC connectors and removable fuses.

Switch-disconnectors provide both load-break-switching and isolation function. DC switch-disconnectors must comply with BS EN 60947, shall not be polarity sensitive and must isolate all live conductors.

Suitably specified double pole DC isolation devices should be installed as close as possible to, or as part of, overcurrent protection devices for both PV arrays and batteries (regardless as to whether they are connected to the DC or AC side of a system).

Effective DC protective devices safeguard equipment against adverse operating conditions and help to ensure that the system is safe. The DC side of the system should be protected from overcurrent and overvoltage.

String fuses are required when the short-circuit current from a number of parallel PV strings is greater than the maximum series fuse rating of a single PV module. String fuses are installed at the point where PV strings are connected in parallel, typically a DC combiner box or inside the inverter. The earthing arrangement for the PV array will dictate whether one or both string cables require overcurrent protection.

³⁴ Fire and Solar PV Systems – Investigations and evidence (S Pester & C Coonick, BRE, 2017)

DC combiner boxes provide easy access and simple arrangement of protective and isolation devices for larger systems. The DC combiner box should be rated for the maximum voltage and current conditions (under stc) of the system and take into consideration segregation between positive and negative parts, permitting safe installation and maintenance and to minimise the risks of arcs. All enclosures should be manufactured using insulating materials with self-extinguishing properties to help minimise the fire risks.

DC insulation faults can occur for a variety of reasons; water ingress, environmental damage to insulation, damage to cables etc. Selecting quality, robust components and following good installation practices will minimise the likelihood of problems developing, however it is important to implement fault-detection measures. Earth insulation resistance and residual current monitoring devices should be utilised to detect insulation faults and trigger earth fault alarms; these can either be incorporated within inverters or provided by separate devices.

There are three types of DC arcs; series, parallel and 'to ground.' DC series arc fault detection is normally provided as a protective device integral to the inverter to reduce the risk of fire should a series arc develop. Rapid shutdown devices are also available that isolate the affected part of the circuit down to PV module level should a DC arc be detected. An assessment should be made of the risk posed by potential DC arc faults and how best to mitigate these within the system.

All DC isolation and circuit protection equipment should be easily accessible and clearly identified on electrical schematics and safe isolation procedures.

Access to any uninsulated conductors and batteries should be restricted and arranged so that it is not possible to touch simultaneously two uninsulated conductive parts with a potential difference of >120Vdc.

8.4 PV modules

All solar carport systems should use certified & CE marked PV modules. Crystalline modules should be certified to IEC 61215 & IEC 61730 and thin-film modules should be certified to IEC 61646 & IEC 61730.

8.5 Solar inverter

In addition to the electrical characteristics of the PV array, the solar inverter(s) should be selected with respect to the distribution network connection capacity available.

All inverters should be CE marked, comply with BS EN 62109 Series. 'Safety of power converters for use in photovoltaic power systems' and BS EN 62116 'Utility-interconnected photovoltaic inverters' and must be either type tested to the relevant Engineering Recommendation (G83/ G59/ G98/ G99) or have an additional G59 relay which has been witness tested by the DNO.

Type testing provides evidence that the inverter will provide the following protection to the distribution network:

- Under-voltage
- Over-voltage
- Under-frequency
- Over-frequency
- Loss of mains

8.6 AC system

As with any electrical installation in the UK, multifunctional solar car park systems are required to be designed and installed in compliance with the current wiring regulations, BS 7671.

8.7 AC Isolation and circuit protection

In order to facilitate safe installation and maintenance, the inverter and EV charge-point must have its own accessible and lockable AC switch that isolates all phase and neutral conductors. This switch may be part of the inverter or EV charge-point.

For multiple inverters, an additional 'main' AC isolator should be installed to disconnect all inverters simultaneously. Often this is facilitated as part of a dedicated sub-distribution board.

All AC isolators should be rated to break the circuits safely while under maximum load.

An over-current protective device should be provided for each inverter and EV charge-point circuit, and RCD protection should be provided in accordance with BS 7671. All protective devices should be selected in accordance with the inverter manufacturer's instructions.

A risk assessment, similar to the one detailed in Appendix E1 of the IET Code of Practice for Electric Vehicle Charging Equipment Installation, should be completed to identify and mitigate any risks of electric shock.

8.8 Cabling

The selection and specification of cables for any electrical system is a fundamental element of the overall system design. Cables should be rated for the maximum voltage and current-carrying capacity for the circuit as per BS 7671 and specified to ensure safety, reliability and to minimise voltage drop and energy losses. Inverters continuously monitor the supply voltage and frequency, and nuisance tripping may occur if there is a significant voltage drop between the distribution network connection point and the inverter.

All cables should be identifiable by colour and alphanumeric marking and selected and installed so as to minimise the risk of earth faults and short-circuits, using double insulated or reinforced cables will help achieve this. PV cables are required to comply with BS EN 50618 'Electric cables for photovoltaic systems.' Consideration should also be given to the routing of cables, ensuring selected cables provide adequate resistance to any environment that they may experience, i.e. moisture, sunlight, heat, chemicals, abrasion or animal damage. AC and DC cables should be separated and clearly identified.

Adequate space should be provided for the routing of cables to enable good installation practices. All cables and connections should be adequately supported using conduit, cable cleats, cable clips, cable ties etc. to minimise the stress from wind or thermal effects and to provide safe continual operation throughout the lifetime of the system.

Particular consideration should be given to the installation and protection of cables from vehicle impact and any on-going land management.

It is usual for DC cables to be run in conduit within the carport structure between the PV arrays and solar inverters, and for AC cables to be armoured and routed underground between the inverters/ EV charge-points and the point of connection.

8.9 System earthing and bonding

Systems earthing must satisfy the requirements of the Distribution Licence issued by the DNO. The design and selection of suitable earthing and bonding arrangements will ensure hazards

are minimised by providing an appropriately low impedance path for earth, fault and lightning currents.

Earthing and bonding of the AC side of the system should be completed in accordance with BS 7671, conform with the requirements of BS 7430 ‘Code of Practice for protective earthing of electrical installations and BS EN 50522 Earthing of Power Installations Exceeding 1kV AC,’ satisfy the DNOs requirements and comply with equipment manufacturer’s instructions.

As per BS 7671, the type of earthing arrangement on the supply circuit (i.e. TN-C, TN-S, TN-C-S or TT) will dictate how adequate protection against electric shock should be. The earthing and bonding arrangements detailed in Table 8.1 should be considered for all multifunctional solar car park systems, and the most demanding requirement applied. Earth cables should be laid parallel and in close contact to DC cables to reduce the risk of multiple paths to earth and should be appropriately sized to afford sufficient conductance.

Table 8.1: Earthing and bonding arrangements.

Earthing/ bonding arrangement	Requirement
Protective earthing	Should be provided for all connections in the energy storage system, and is also required for the carport frame if it is considered to be an exposed conductive part.
Functional earthing	Is required for all components with an AC connection (i.e. inverters, EV charge-points, control and distribution equipment).
Protective equipotential bonding	Required if any parts of the system are considered to be an extraneous conductive part. EV charge-points and batteries (installed in metallic enclosures separate from the inverter/charger) normally require equipotential bonding.
PID earthing	As per the PV module manufacturer’s instructions
Lightning protection	Required if a lightning protection system is required on site, or if the solar carports are in close proximity to an existing lightning protection system.

8.10 Metering

The energy metering system should include electrical meters for the:

- Electricity generated (at point of generation)
- Electricity exported (at the point of connection between the installation and the distribution or transmission network)
- Electricity used by the EV charging points

The works must include the incorporation of metering to monitor cumulative energy generation (kWh) and rated output (kW) which is compatible with the BAS Energy Monitoring System provided by Elcomponent.

All metering to record generation or export for FIT payment purposes must comply with specific metering legislation³⁵.

Note: An MID (Measuring Instrument Directive) approved generation and export meter is required to claim financial incentives under the Feed-in-tariff (FIT) scheme.

³⁵ The definition of “metering legislation” can be found in Schedule A to Standard Condition 33 of the Electricity Supply Licence.

8.11 Lighting and surge protection

The possible effects of a direct or indirect lightning strike need to be considered. A lightning and surge protection risk assessment, including of data or control circuits and existing lightning protection system (LPS), should be carried out according to BS EN 62305.

If the risk assessment indicates the need for lightning and surge protection then appropriately rated devices must be selected and installed in the correct lightning protection zone (LPZ) as detailed in BS EN 62305. For multifunctional solar car parks this will normally mean the installation of Type 1 and/ or Type 2 surge protection devices (SPDs), details of their function are presented in Table 8.2.

Table 8.2: Function and typical location of surge protection devices.

SPD Type	Function	Typical Location
Type 1	Discharges very high levels of lightning current.	AC side of the equipment and at the distribution network connection.
Type 2	Diverts lightning induced surges to specific components or parts of the system.	DC input of the solar inverter (can come pre-fitted to the DC combiner box)
Combined Type 1-Type 2	Combining both the above functions.	AC side of the equipment and at the distribution network connection.

9 Mechanical design considerations

9.1 Structure

Regardless of the type of solar carport frame, (i.e. V-frame, T-frame, portal-frame etc.), the structural integrity of a solar carport frame is fundamental in ensuring that a system is fit for purpose.

Compliance with BS EN 1990:2002+A1:2005 'Eurocode. Basis of Structural design' and BS EN 1991-1 Series. 'Eurocode 1. Actions on Structures', ensures that structural safety and loading characteristics are accounted for in the design of a solar carport.

BS EN 1991-1-7:2016+A1:2014 and the accompanying UK National Annex provide strategies for safeguarding against impact forces from vehicles and normalisation of impact loads from vehicles as static loads acting on the solar carport structure.

Adherence to BS EN 1993-1 Series. 'Eurocode 3. Design of steel structures' is required for any solar carport that includes a steel structure. In addition, solar carport foundations and columns may require geotechnical design of spread foundations, piles and retaining structures as per BS EN 1997-1:2004+A1:2013. 'Eurocode 7. Geotechnical design. General rules'. For any concrete members of a solar carport, reference should be made to BS EN 1992-1-1:2004+A1:2014 'Eurocode 2. Design of concrete structures. General rules and rules for buildings.'

Compliance with Government guidelines on materials and workmanship³⁶ as presented in the Building Regulations (2010) ensures that best practice in both design and construction is carried out. This guidance includes determination of expected loading capabilities and ground

³⁶ Building Regulations (2010) Approved Document 7 Materials and Workmanship (Department for Communities and Local Government, 2013).

movement potential in relation to location and prevalent environmental conditions, such as average wind speed³⁷.

Design durability of a solar carport can be defined as the ability for the structure to have no to low maintenance for a minimum of 20 years³⁸ and therefore steps should be taken to ensure that the materials chosen are robust and resistant to medium and long term environmental exposure.

Critical to durability are the connections of structures, such as between purlins, supporting beams and column connections, where ingress of moisture and water over time can lead to corrosion or degradation of the structure unless adequate protection measures are provided³⁹. Consequently the solar carport design and materials must be evaluated on a site by site basis to ensure sufficient and durable protective measures against corrosion or degradation have been fully considered and implemented.

Solar carports that do not fit within the definition of steel structures as detailed in BS EN 1993-1 Series, must instead be compliant with the relevant section(s) of BS EN 1090 Series. 'Execution of steel structures and aluminium structures.'

All steel construction products should be certified under the CE marking framework⁴⁰. Consideration should also be given to the Construction Products Regulation⁴¹.

9.2 Carport frame

The solar carport frame should be manufactured from corrosion resistant materials that are appropriate for the environment in which they are to be installed and that are suitable for the expected lifetime of the system. Galvanic effects should be considered when selecting a frame that uses components of different metals. The design should make allowances for thermal expansion and contraction i.e. providing expansion gaps in structures with long extrusions. In addition, the design and specification of the carport should prevent the accumulation of snow, ice, water and debris on the PV array.

All PV module clamping should be carried out in accordance with manufacturer's requirements.

9.3 Loading

The carport structure, ground fixings, PV modules and mounting fixings need to be able to withstand all forces that are anticipated to be imposed on them throughout the lifetime of the system.

9.4 Foundations

In addition to the requirements stipulated by Part A of the Building Regulations, all foundation types should conform to BS 8004:2015 'Code of practice for foundations' and BS EN 1997-1:2004 + A1:2013 'Eurocode 7. Geotechnical design'.

³⁷ Building Regulations (2010) Approved Document A Structure denotes average wind speeds for England and Wales, used to determine design loads of wind actions on solar car park structure and mounting system (Department for Communities and Local Government, 2013)

³⁸ Design Criteria for Structural Solar Supports for Parking Canopies Installations (Structural Solar LLC, 2013)

³⁹ Corrosion protection measures include hot dip galvanization and corrosion resistant paint coatings. Durability, Lifespan and Economics Cost of Solar Carports (Structural Solar LLC, 2013)

⁴⁰ Steel construction products must be certified under the CE marking regulations as presented by the BSI Update to the BS EN 1090 Marking for structural steel and aluminium fabricators (BSI, 2014).

⁴¹ http://ec.europa.eu/growth/sectors/construction/product-regulation_en

Solar carport structures can be affixed to a surface car park by either penetrating or non-penetrating methods. The decision as to which method is suitable for the BAS car park will come down to the site conditions ascertained by geotechnical data and investigations. For example:

– Surface car parks - soil structure, flooding, ground stability, surface finish and underground activities (i.e. underground services, archaeology, previous site activity, contaminated land etc.).

Consideration should be given to the permanence of the foundations, it may be a requirement of the planning consent that the system should be fully removable at the end of the systems useful life.

9.5 Surface car parks

Foundation solutions suitable for surface car parks tend to fall into two categories; piles or spread foundations (i.e. concrete pads and ballast). Spread foundations should generally not be used on engineered fill⁴².

In general foundation design should take into account; the stability of the ground (i.e. potential for post-construction settlement, presence of weak layers, shear failure due to the construction process etc.), the effect of groundwater and drainage, potential global ground movements that can stress or deform the foundations and the construction of the foundations.

10 Solar Carpark layout

Solar carpark should be laid out to facilitate safe car park operations. The solar carpark should maintain the same layout as the current carpark with the exception of part of the existing space available for cars to be lined appropriately for the use of motorcycles that are currently parked at the north carpark area of BAS Cambridge site.

10.1 Underground services

The layout of the solar car park system should take account of other services installed at the site, including those located underground, and especially those that require access. Information on underground services can be found in Appendix B: Existing underground services of the car park area.

Enquiries and surveys should be completed during the project planning stages to understand and map out all car park installation and operational activities and how these might impact on other services. Particular attention should be given to areas requiring excavation and/or penetration for foundations or trenching for cables.

10.2 Component layout

A number of the components installed in the solar car park may present a health and safety risk to system installers; users and the general public if they are not located and installed according to the manufacturer's instructions. When selecting locations for components, thought should be given to; minimising the requirement for working at height and manual handling; the weight of individual components and the integrity of the structures to which they are to be attached; any noise from components when in operation; ease of installation; maintenance and decommissioning.

Particular attention should be given to the following:

⁴² BS 8004:2015 Code of practice for foundations (BSI, 2015)

10.3 Protection from damage

It is necessary to consider the layout and location of all equipment installed within the car park to reduce the risk of damage from vehicle impact. Where it is not possible to locate equipment in a position that minimises the risk of damage, then additional protection should be provided as defined in BS 7671 (impact severity AG2). In addition, system components should be protected from vandalism or abuse, either by being placed out of reach or through selecting devices with anti-vandalism and/or anti-tampering features.

Carport structures should be designed to withstand vehicles impacting the structure at speeds of up to 20mph. This is described by BS EN 1991-1-7 'General Actions. Accidental Actions'.

The power conversion system and other equipment may be installed in a building or delivered to site in ISO shipping containers. Where ISO containers are used, suitable foundation pads or raised supports to eliminate the risks from flooding, ingress of snow or ice. External protection, such as bollards, should also be provided to prevent damage from vehicle collisions.

10.4 Environmental protection of equipment

Attention should be given to the location and layout of all components of the solar car park to ensure that manufacturer's instructions concerning protection from environmental conditions are followed. Environmental conditions which could be detrimental to solar car park equipment include:

- Ambient temperature range
- IP rating
- Maximum humidity
- Ventilation
- Maximum altitude

All components should have a suitable IP rating for their installation location, as detailed in BS EN 60529. This should include consideration of where they are to be located (i.e. flood zones), any activities or incidents that may take place in or adjacent to that location (i.e. car washing, PV cleaning, burst water pipe).

Moisture ingress into enclosures containing DC components is the main cause of fire incidents involving PV⁴³ and therefore due care should be given to preserving the IP rating of components through good installation and maintenance practices. Cables should be routed and suitably protected from environmental conditions for their full length, i.e. through correct installation of appropriate conduit, trays and cable glands.

Equipment that has the potential to create a spark (such as DC isolators) should not be located in areas where flammable gases, combustible materials or explosive atmospheres (including dust) may build up. In addition components should not be located near heat sources or sources of ignition.

Components of heating and ventilation systems, e.g. compressors, pumps and fans, may be a source of noise which that will need mitigation.

Adequate protection against fire (ingress and spread) must be provided in accordance with local fire regulations. Whilst these risks are small in carefully designed and installed systems, the potential impact of an incident should not be overlooked.

⁴³ Fire and Solar PV Systems – Investigations and evidence (S Pester & C Coonick, BRE, 2017)

10.5 Accessibility

During both construction and operation, access to a multifunctional solar car park needs to be carefully considered. This includes specific access requirements for construction equipment, large delivery vehicles (i.e. HGVs), and emergency vehicles accessing and traversing the car park. In particular, the solar carport and equipment layout needs to provide suitable access, including to isolation switches, for emergency services.

All components within the system will require some maintenance throughout their lifetime and it is important that provision is made for this. It must be possible to access all serviceable equipment, including being able to remove covers. Particular consideration should be given to how serviceable components (such as inverters and fuses) will be accessed, and potentially replaced, during the lifetime of the system.

Carport structures that do not require access onto the roof canopy during the construction and maintenance phases are preferable. This can be achieved using mounting solutions that give access to modules from underneath the canopy. Minimising the need to access the roof also protects the PV modules from damage which could lead to underperformance or an electrical fault.

Access must be restricted to any live connections or terminals.

EV charge-points do require good accessibility for the users. At present the inlet position (the charging socket on the vehicle) has not been standardised. This means particular consideration needs to be given to how to facilitate connection between an EV charge-point and vehicle inlet position whilst minimising the length of charging lead (to reduce trip hazards and to prevent accidental damage to equipment and vehicles).

All EV charge-point socket outlets should be installed between 0.75- 1.2m above ground level.

10.6 Commissioning

Commissioning procedures should include full inspection and testing of the complete system according to the requirements of the component manufacturers, BS 7671, BS EN 62446-1 and the appropriate ENA Engineering Recommendation.

A visual inspection should verify that the system complies with current standards and has been installed according to the agreed design and manufacturer's instructions, using appropriately specified, selected and undamaged equipment. Electrical and functional testing should be completed, ensuring that all protective and isolation devices operate as required. Functional tests of the control and operational systems should also be completed, including ventilation, fire protection and systems relying on internet connectivity.

Depending on the requirements of the DNO, an additional witnessed test of the operation of the G59 relay may be required prior to connecting the system to the distribution network.

A complete operations and maintenance manual should be provided to BAS that includes:

- Copies of all commissioning, inspection, testing and risk assessment documents
- Copies of the grid connection agreement and protection settings
- The system technical specification
- Copies of as-built system drawings
- Component manufacturer's manuals
- Warranty/ guarantee details
- Operating instructions
- Emergency shutdown procedures

- Maintenance instructions and schedule
- Decommissioning and disposal instructions
- The names, addresses, telephone and fax numbers of appropriate contacts during the daytime and night time in the case of a fire, leaks, breakdowns,

11 Operation and Maintenance contract

The Contractor should allow for a three year service contract after defects on annual health check of the array by the installer.

12 Warranties

BAS requires a performance warrantee for the system of at least:

- 25 years against 80% output
- 12 years against 90% output

Inverters warranty should guarantee 12 years without failing.

All additional warrantees are to be clearly stated within the tender return.

13 Training

Training for site electricians specifically for safe isolation of dual supplies and fault finding on inverters should be included in the costs.

14 Feed-in-Tariff scheme

The Contractor should ensure that all requirements of the FIT Order for the installation to be commissioned are satisfied and submit an application to receive preliminary accreditation under the FIT scheme.

To realise the benefits of preliminary accreditation, the installation at Phase 1 (solar carports at the four (4) double bays of the carpark) must be commissioned and an application must be prepared and submitted by the Contractor to convert preliminary accreditation to full accreditation, both within the validity period.

The Contractor should ensure registration with Ofgem in order for BAS to receive benefits under the FIT scheme for Phase 1 products.

Appendix A: Existing drawing of the car park area

Appendix B: Existing underground services of the car park area

Appendix C: Onsite energy consumption profile (HH data), cost and carbon conversion data

- Onsite energy consumption profile – HH data (kWh) for 2017 in attached excel file
- Electricity bill: 0,12 £/kWh
- Electricity carbon conversion factor for 2017/2018: 0.35156 kgCO₂e per kWh