

BRE National Solar Centre

Solar car parks

A guide for owners and developers



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BRE National Solar Centre provides expert advice and training on solar carports and many other solar related topics. See www.bre.co.uk/nsc for more information.

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Scope

Installing solar systems above surface and multi-storey car parks is becoming increasingly popular. The area above a car park is an otherwise unexploited brownfield site that can be used to generate renewable energy. There are over 17,000 parking facilities in the UK and the sector generates £1.5 billion per annum¹. Solar carports can enhance the car-parking experience in a number of ways, as well as improving the economic and environmental performance of the asset.

This document is aimed at purchasers and developers of solar carport systems. It provides an outline of all the key factors in site selection, solar carport design requirements and business case formation. Solar carports are a relatively novel form of deployment, and there is little published data on costs. The costings given here are indicative of the contributors' experience of deployments to date. Solar carport installation costs are expressed in both £/Wp and £/m² in order to aid communication between the solar and construction industries. Revenue streams are expressed in £/car parking bay/year.

The guide is published with an accompanying financial model, designed to be compatible with the above costs and revenue streams. Armed with these tools, it is hoped that key decision makers will better understand solar carport technology and deployments will increase.

Business case formation

Solar carports can benefit from a number of potential revenue streams in addition to power sales. These should all be considered in the process of building the business case.

Modelling solar revenue streams

The underlying financial model for electricity revenues is similar to that for any PV system and is not discussed in detail in this guide. PV deployment has been rapid over the last five years or so, following the advent of the Feed-In Tariff (FIT) and the falling costs of the technology. Whilst subsidies are still potentially available, accessing them is becoming increasingly challenging. In any event, as the cost of PV continues to fall, subsidies are no longer the main stimulus to deployment. It is therefore advisable to consider the business case on the basis of unsubsidised generation, with the potential for an additional upside if a modest amount of subsidy should prove available.

It is likely that the owner of the car-park will have an on-site electricity demand or be located near to a potential purchaser. Self-consumption or direct sale to an end consumer will result in greater income than selling the power wholesale to an electricity supply company.

In the section on site selection we will cover in more detail how to optimise the choice of a carport system where the customer has a large portfolio of car parks sites from which to choose.

Modelling non-solar revenue streams

The following examples give approximate incomes for additional revenue streams.

Electric vehicle (EV) charging



An EV charging point, photo courtesy of SunGift Energy

There is clearly a synergy between solar carports and EV charging. As of January 2016 there were approximately 48,000 registered EVs in the UK². National Grid estimates that there could be over one million EVs on the road by 2022³. Dual siting of solar carports with EV chargers can significantly reduce the installation cost of the latter and provide shelter for the EV charger user.

Revenue generation from EV chargers is a fast-moving and developing market. The three largest EV charging networks, Chargemaster, Ecotricity and Podpoint, are moving towards charging models, with pricing dependent on the speed of charge. There are three main EV charging speeds, with capital costs ranging from less than £1000 fully installed, to over £20,000 per unit.

¹ The size and shape of the UK parking profession, BPA 2013

² Electric car market statistics (next greencar)

³ National Grid (2015) Future Energy Scenarios

- **Slow charging** (up to 3kW) - which is best suited for charging domestic vehicles overnight. This takes around 6-8 hours. Slow chargers are being phased out in public locations in favour of fast and rapid chargers.
- **Fast charging** (7-22kW) - which can fully recharge some models in 3-4 hours.
- **Rapid charging units** (43-50kW) - which are able to provide an 80% charge in around 30 minutes. Rapid chargers also come in two charge point types (AC and DC) depending on whether they use alternating or direct current.

EV units can be purchased outright, leased, or alternatively space can be rented out to third parties. Several companies specialise in providing free and chargeable EV infrastructure. Many believe that the industry trend is to bill up to £0.40/kWh for rapid charging and £0.25/kWh for fast charging. Current business models assume a revenue of £480/unit/year for a fast charger (based on dispensing two charges per day) and up to £48,000/unit/year for each rapid charger (for prime locations and a high customer turn around). The number of EV charging stations and the frequency of use are important factors in the choice of charging speed and the number of charging points.

Installing solar carports and EV infrastructure at the same time gives the benefit of cost savings and EV infrastructure future proofing; for example electrical cabling and trench costs can be shared between the two technologies and EV units can use the electrical infrastructure of the solar carport.

A final important consideration for EV charging infrastructure is the demand on the local grid. Without substantial grid upgrades a typical light commercial connection is unable to support more than one rapid charging unit. The cost of this upgrade, known as the reinforcement cost, is site-specific and can range anywhere from several thousand pounds to well over a million pounds. Integrating EV chargers with solar carports and an energy storage system would ensure that the EV chargers do not interrupt local power availability, although there will be a capital cost implication. In such situations where significant grid upgrades are required, integrating EV charging and storage into the structure of the carport may be a cost-effective method of deploying the system.

Advertising

Advertising in car parks forms part of the Out of Home (OOH) advertising segment, of which the largest agencies are JC Deceaux, Clearview and T4 media. Smaller local and car park specialist agencies also exist such as Infocus Media and Adverticket. Nationwide car park operators NCP and APCOA also offer managed car park advertising on sites.

When building advertising into a business case, the key information to have at hand is the car park footfall (i.e. the number of visitors per day) and the car park user's demographic. An agency should then be able to assist in proposing a solution.

Advertising locations are principally on pedestrian entrances and exits and vehicle barriers. The typical revenue from an advertising hoarding, depending largely on car park footfall, is in the range of £12-24/bay/year.

Premium parking

A surface car park is usually uncovered and open to the elements. The construction of a solar carport allows the vehicles and users to be sheltered from the sun and rain. Surface car park revenue varies widely depending on many factors such as location, frequency and duration of usage, typically between £5,540-£9,000/bay/year. Covered parking can demand a premium of up to £720/bay/year.

LED lighting

Many car park owners are converting their car park lighting to LED technology in order to benefit from lower power consumption. Lighting a car park to the required standard using non-LED technology has a typical energy cost of £36/bay/year. Canopy under-lighting and LED technology is effective at reducing this cost, while also reducing light pollution. The use of LED lighting should reduce the electricity consumption required for lighting by around 50%, representing a cost saving of around £18/bay/year.

Replacement of lighting in a car park is an opportunity to consider wider redevelopment of the property and to include solar car parking. Additional value added systems such as light sensors, motion sensors and empty bay signalling systems are available, but are not discussed in this guide.

CRC Energy Efficiency Scheme

The CRC Energy Efficiency Scheme is a mandatory carbon emissions reduction scheme. It currently applies to organisations in the public and private sectors consuming over 6,000MWh per year⁴. Scheme participants account for over 10% of UK CO₂ emissions and include large retail chains, manufacturers and many government bodies.

In order to encourage energy efficiency measures, annual allowances for missed energy reduction targets must be purchased. These can be purchased from the Government (currently costing £16.40 per tonne of CO₂ (equivalent to £0.027/kWh)) or from the secondary market. For companies required to purchase extra allowances, solar carports can represent a revenue stream of £46.30/bay/year based on an average-yielding solar array. It should be noted that this revenue cannot be claimed if the solar system is receiving a feed in tariff.



The Olympic park carport under construction
Photo courtesy of Sundog Energy

⁴ It is administered across the UK by the Environment Agency in England, by Natural Resources Wales, the Scottish Environment Protection Agency and the Northern Ireland Environment Agency.

Brand value

DECC regularly carries out surveys on public attitudes towards different sources of power generation⁵. The results consistently show PV to enjoy the most support. Over 80% per cent of the population supports the technology, and a solar carport provides a strong statement of an organisation's commitment to carbon reduction. Estimating brand value is beyond the scope of this guide.

Customer footfall

A recent report concerning a German solar carport installation in a retail park, observed an increase in customer visits⁶. For customers who earn revenue from leasing retail units, such an effect could ultimately result in higher rental income. Retail park owners should consider the retail business model that they operate and the potential benefit of solar canopies on customer behaviour. Estimating footfall and increased retail revenues is highly site dependant and beyond the scope of this guide.

Funding models

Public sector clients

The public sector has access to low-cost, long-term infrastructure funding in the form of the Public Works Loans Board. This organisation is able to borrow at government rates and issue loans for 20 year terms, for about 3% payable on interest only. This is lower than any private sector organisation and it allows the loan to be repaid from the solar carport revenue. The process of application is relatively straight forward. A business plan is required to illustrate that future revenue streams will fulfil the repayments.

Many public sector organisations, including councils, have large capital reserve funds. Councils receiving low rates of return on their cash reserves often look to finance income-generating schemes such as renewable energy projects.

The government is considering grants for EV charging and energy storage infrastructure, but at the time of writing no further information was available. Should these become available, they could also form part of the business case for carports.

Private sector clients

Private sector lending rates for solar PV projects are in the range of 7.5-8.5% depending upon credit risk and project size. Such funds would expect to be repaid from the revenue for power generation or other agreed revenue streams.

Power Purchase Agreements (PPAs) are well-established in the solar PV sector. Land owners lease their rooftop or car park to a financial institution, which then contracts a developer to deploy a PV system. The land owners or another off-taker undertakes to purchase power at an agreed price.

Finally, commercial mortgages represent the lowest cost of borrowing for the private sector, with lending rates in the range of 3-5%.

Financial modelling

A financial model is published with this report and can be downloaded from the BRE website⁷. Developers and car park owners can use this model to explore the impact of design decisions and business cases on the financial viability of a solar carport project. The model is in MS Excel format and is capable of calculating the Internal Rate of Return (over 25 years), Net Present Value (over 25 years), FIT Revenues (over 20 years) and Lifetime Cost of Electricity (over 25 years). Green cells represent the input assumptions such as build cost, PV system size, annual yield, FIT rate, energy price inflation and operations and maintenance costs. The model is free from copyright and was developed by the author and Samantha Peverley.

⁵ The "Public Attitudes Tracker" is conducted quarterly. See <https://www.gov.uk/government/statistics/public-attitudes-tracking-survey-wave-16>

⁶ http://www.solarpowerportal.co.uk/editors_blog/can_carports_drive_a_new_wave_of_solar_deployment_3425

⁷ www.bre.co.uk/nsc > Our Library > BRE Publications

Site selection

Car park layouts

Organisations can significantly increase the financial performance of solar carports by choosing appropriate sites for installation. The car park layout that lends itself most favourably to low-cost solar carport installation is long, double rows of car parking adjacent to high energy users. Hospitals, airports, retail parks and large commercial premises often present such layouts.

Other considerations

There can be a trade-off between maximising financial performance and maximising renewable power generation. It is therefore important that the customer chooses early-on which strategy is most consistent with its values.

For maximum financial performance, the developer is advised to select properties which fulfil the greatest number of criteria in Table 1, which shows how several site selection and design factors will impact on Internal Rate of Return (IRR). The factors are grouped into three levels; high, medium and low depending upon their relative impact on the financial viability of a solar carport project. Developers should focus their attention on satisfying the criteria for the higher and medium levels if they wish to maximise the financial performance of the project.

Table 1 Site Selection and Design Criteria

Impact on financial viability	Site selection & design factors
HIGH	On-site energy usage & Distribution Network Operator (DNO) capacity On-site energy usage of the electricity generated typically gives the greatest returns. With retail electricity costing between 9-13p/kWh, many users stand to gain by internally-consuming solar electricity power or by selling it to adjacent properties. A secondary limiting factor is the grid connection capacity at the location of the solar carport. The DNO can advise on the cost of grid connection. If there is little capacity available, the cost of grid connection can increase dramatically. Export limiting devices can potentially be used to mitigate against this issue.
HIGH	Surface carports & multi-storey carports There are some significant differences between installing solar carports in ground level car parks and on the top deck of multi-storey car parks that need to be considered at an early stage of the site selection process. One of the main differences is that costs are usually lower for surface car parks than for top decks of multi-storey car parks.
MEDIUM	Feed-in Tariff The FIT is continually reducing and is now subject to a new system of quarterly deployment caps. Being able to access a FIT is therefore no longer guaranteed. Therefore, it should be modelled as a potential upside, but the business case should not hinge upon it. For the latest information on FIT rates and progress towards reaching the caps, see https://www.ofgem.gov.uk/environmental-programmes/feed-tariff-fit-scheme/tariff-tables
MEDIUM	PV panel shading Car park and rooftop solar PV can be subject to shading from adjacent buildings and foliage. Care should be taken to avoid these issues, with reference to tree protection orders and future planning permission of adjacent properties. If shading cannot be avoided, technologies such as PV panel optimizers can be used.
LOW	Annual solar potential Annual solar potential is the amount of sunlight falling on a given location in the UK. The South of England and Wales can receive 1100W/m ² per day whereas parts of Scotland receive 900W/m ² per day. For further information, see the solar irradiation datasets ⁸ . However solar power installations are seen throughout the UK and local weather conditions also factor into the solar potential.
LOW	PV array orientation Aligning PV arrays to the optimal south-face orientation is often not possible due to existing car park layouts. Carpark redevelopments and resurfacing may present the opportunity to optimise for a solar carpark layout. The orientation of a duopitch system has no impact on annual electricity yield, whereas the yield of a monopitch system is sensitive to orientation.
LOW	Carport frame The V-frame is the most cost-effective design but has the disadvantage of a footprint into the car park bay. The T-frame is roughly 10% more expensive than the V-frame but it avoids extending a footprint into the bay. Portal-frames can also be a cost effective design, and supports larger solar arrays compared to other designs. These frames are illustrated in Table 2.
LOW	Carport rows The carport foundation is the same cost for both the single and double structures. Therefore, it is more cost-effective to install double rather than single carports. The longer the row, the more cost-effective the installation due to economies of scale.
LOW	Carport weatherproofing and guttering Removing flashing or guttering details from carports would reduce project cost and thus increase the IRR. However, this should be set against the detriment to user experience.

⁸ <http://www.microgenerationcertification.org/mcs-standards/installer-standards/solar-pv>

Carport design

In this section we will discuss the principle four components of carports: frames, roofs, foundations and PV systems. Solar coverings for car parks range from basic, modular structures aimed to maximise financial performance, to bespoke designs which aim to make an architectural statement. The former should be able to offer a PV system capacity of 2kWp per car parking bay, covering 12m², with costs in the range of £900-£1400/kWp (£150-£233/m²) for all four components. Whereas the latter bespoke designs typically feature lower PV capacity and higher installation costs. The cost of installing carports at the best car park sites is therefore comparable with the more challenging commercial rooftop projects. Where reinforcement is needed, and there are additional costs for access equipment, a commercial roof PV installation currently costs £800-£1000/kWp (£133-£166/m²).

Surface carpark and multi-storey carpark sites

Surface car parks represent the most common deployment of solar car parking. The advantages of working at ground level removes many of the costs associated with solar rooftop systems. A large factor in the cost of such systems are the foundations. Appropriate site selection is the most effective way of reducing deployment costs.

Multi-storey car park top decks are a common site for carports, but pose more engineering challenges than surface car parks. Carports designed for the top decks of multi-storey car parks are higher in cost, due to a number of factors: costs of access for materials, the necessary edge protection to ensure safe working at heights, and greater structural constraints. The construction and structural capacity are the main factors in determining the design and specification of the carport frames on the top deck of a multi-story car park. The frames and the fixings need to be able to withstand the significantly higher wind loadings and in some cases the top deck of a multi-storey car park may not be structurally suitable for the installation.



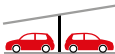





The benefits of installing solar carports on the top decks of multi-storey car parks is their usual proximity to sites of high energy usage. Higher onsite usage of electricity often maximises the financial returns of PV systems. Additionally, being significantly higher than ground level car parks they can also potentially suffer less shading related issues, although this is not always the case. Finally, the shelter from wind and rain may also be more beneficial for the user of a top deck multi-storey carpark than a surface carpark.

Frame and roof types

All designs can be classified according to the position and number of columns, and the angle of the roof. Table 2 displays the most common variations, provides a classification system, and sets out the engineering terminology for describing various canopy structures.

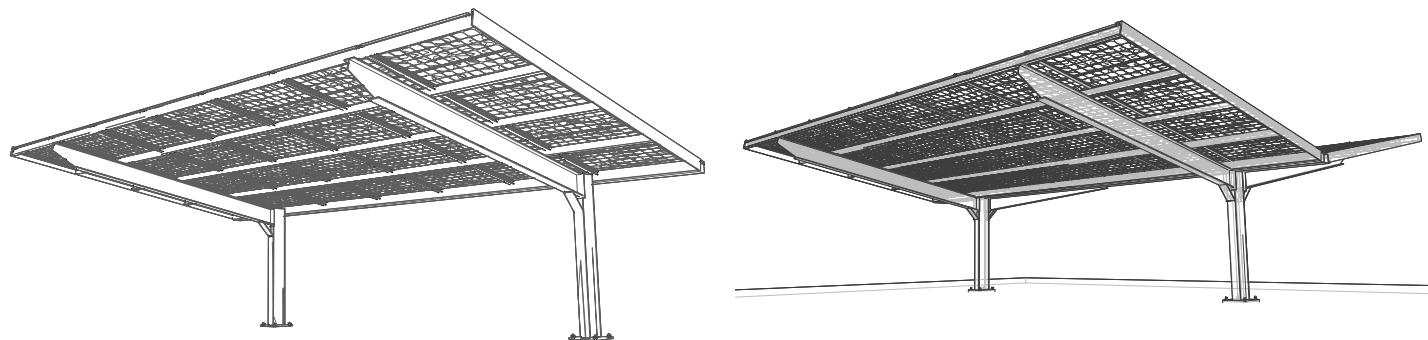
T-frame, V-frame and Portal-frames are the three most common structural designs. Their respective advantages and disadvantages are discussed in this section. Monopitch, duopitch, barrel-arch and beam roof are common roof designs and their performance is also discussed.

Table 2 A classification system for carport designs

	Monopitch canopy		Monopitch canopy		Duopitch/gull wing canopy	
Single row of cars						
	T-frame single Un-balanced, un-braced cantilever, monopitch, single bay	V-frame single Balanced, braced cantilever, monopitch, single bay				
Multiple rows and aisles			Portal-frame canopy			
						
			Portal-frame barrel arch Balanced, braced non-cantilever, barrel roof, multiple bay	Portal-frame beam roof Balanced, braced non-cantilever, beam roof, multiple bay		

T-frame structures

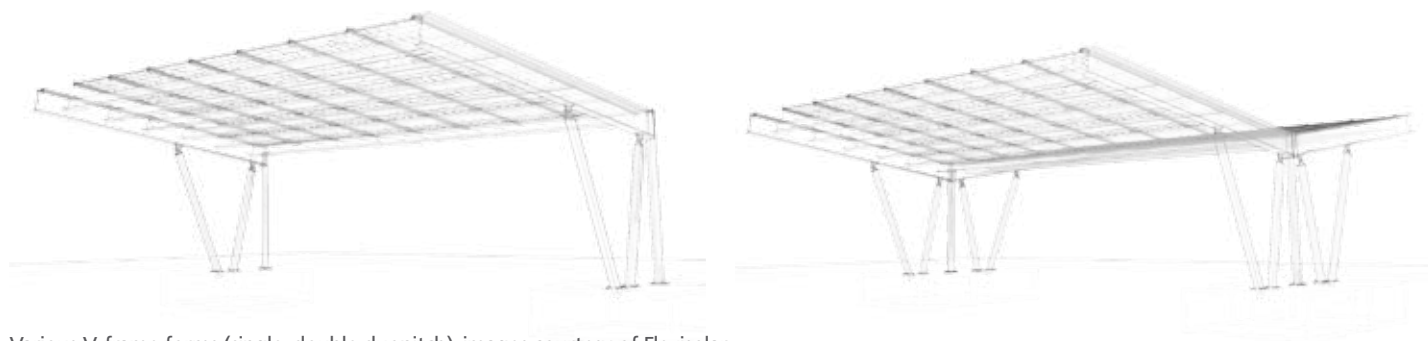
T-frames with unbraced cantilever roofing beams, have columns in the centre of the structure. The single columns are sited on or near the back markings of the car parking bays. The advantage of this structure is that the carport does not inhibit the user when parking a vehicle. The disadvantage is the increased cost due to the greater amount of steel used to support the larger overhanging area.



T-frame forms (single, double duopitch), images courtesy of Flexisolar.

V-frame structures

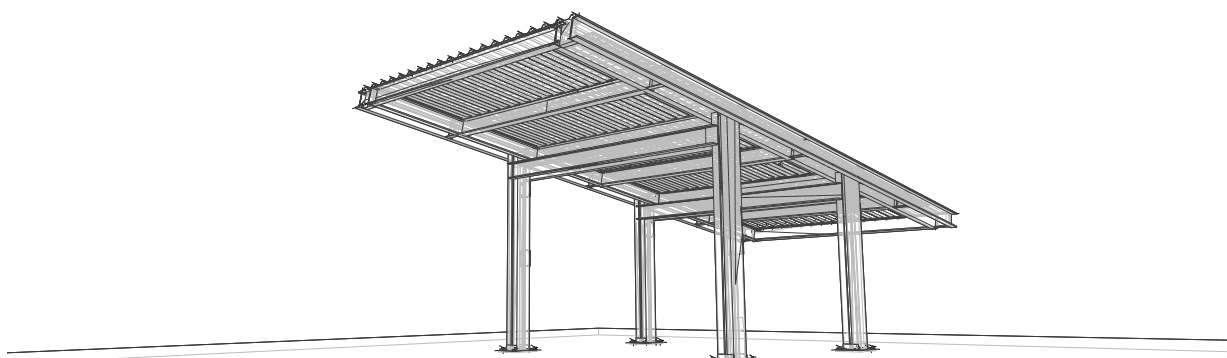
V-frames with braced cantilevers have combinations of vertical beams and diagonal struts. Struts can be sited along dividing markings of the car parking bays so as not to obstruct vehicles. Bay dividing line markings are typically 100mm wide, which is sufficient width for the struts. The advantage of this structure is that it is the most cost-effective framing method for large-scale car parks and provides space for inverters and other electrical equipment to be mounted inside the V-frame and away from possible vehicle collision.



Various V-frame forms (single, double duopitch), images courtesy of Flexisolar

Portal-frame Structures

Portal-frame structures with balanced, braced and non-cantilever roofing beams cover both the car parking bays and aisle(s). The advantage is that they provide full shelter to the car park user and comprise a larger area for solar panels. The disadvantage is that additional steel is required to span the distance between parking bays and aisles.



A Portal-frame, image courtesy of Flexisolar

Monopitch roof

In parking bay orientations that face anywhere between south west to south east, a monopitch design is likely to generate more electricity than other designs. It should be noted that guttering for monopitch carports can be more complex, requiring an unsupported down pipe to dog-tail back from the overhanging eaves to the structure. Unsupported guttering can be prone to damage and so care should be taken when designing a monopitch guttering system.

Duopitch roof

Duopitch (or gull wing) solar carports have apexes at the front of the rows and a valley running in the centre of the two car parking rows. This orientation is very similar to the east-west commercial roof top installations. This extends the duration of generation at dawn and dusk, which normally correlates better with the energy demand of the building. Duopitch systems provide the same annual energy yield regardless of their orientation.

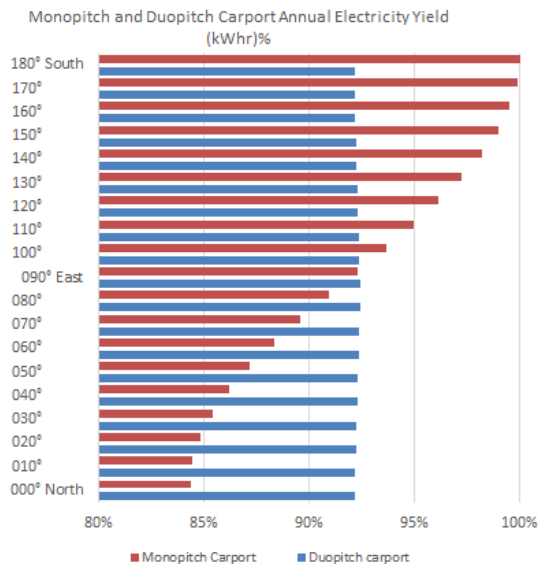
Monopitch and duopitch comparative performance for PV systems

A monopitch PV system facing south will always generate more energy than a duopitch roof, but car parks are rarely laid out to make this possible. Figure 1 shows the energy yield of a monopitch PV system (red) is highly dependent on the orientation. The duopitch PV system (blue) is independent of orientation and provides 92.5% of the yield of a south facing monopitch PV system. If a monopitch PV system is facing through north to east then it will produce less energy than a duopitch PV system in any orientation.

It is important to consider the electricity load profile of the properties supplied, as certain orientations of roofs will provide more power at certain times of the day. Ultimately, however, the difference in performance between monopitch and duopitch roofs can often be less relevant than the visual impact and user experience.

Both monopitch and duopitch carports typically have a roof slope (aspect) of 5-10° and this is considered to be the optimum for a carport structure. Roofs sloping more than 10° can pose problems with the visual appearance and user experience.

Figure 1 Monopitch and duopitch roof design impact on annual electricity yield



PV system roof integration

The majority of residential and commercial PV rooftops are retrofitted onto pre-existing roofs. Installing PV panels onto a pre-existing roof results in a double roof structure. Some carport designs adopt this method for new-build carports, choosing to mount panels on top of sheet roofing or similar. This is often done to simplify the design, and benefit from the cheap availability of common components and skilled labour. In areas of high risk of vandalism, double roof structures offer a permanent screen between the PV system and the general public.

PV glazing systems replace the roof with PV panels such that the panels form both the roof and the PV system. This can be achieved with specially-designed mounting and sealing solutions that ensure water tightness and structural strength. A well-executed PV glazing system should use fewer materials and reduce project costs. PV glazing systems also allow a quantity of daylight through the canopy, improving the appearance of the structure.



A double roof structure, photo courtesy of EvoEnergy

Foundation options

Ground foundations make up a significant component of solar carport costs. There are four foundation solutions suitable for solar carports; helical screw piles, concrete piles, concrete pads and above-ground ballast. The choice of solution is very site-specific and depends mainly upon site ground conditions or the structural capacity of multi-storey car park top decks.

Helical screw piles are steel corkscrews of between 1-6m in length that are screwed into the ground once a small square of tarmac has been removed. Under normal conditions these are the cheapest foundation solution, and are sustainable as they can be removed and reused at the end-of-life of the structure.

Concrete piles are long lengths of reinforced concrete piled into the surface. They have the advantage of requiring less concrete than pad foundations, but require the removal of about twice as much tarmac surface when compared with helical screw piles. This method is often used in costly railway and communications construction, where ground conditions vary and this solution is suitable for a wider variety of terrain than helical screws.



A concrete footing, photo courtesy of EvoEnergy

Concrete pads are typically 8m² with a depth of 1m. Pads are suitable for a wide variety of soil types but have major drawbacks. The large amount of concrete needed makes this costly and the least environmentally sustainable foundation solution. Further, the curing time of concrete adds at least seven days to the construction cycle and large volumes of soil will require disposal.

Above-ground concrete ballast is another method. This reduces amount of below-ground foundation, however it has the disadvantage of occupying a large footprint on the surface of the car park.



Steel pins for installing with concrete piles
Photo courtesy of Evoenergy

Solar PV panel options

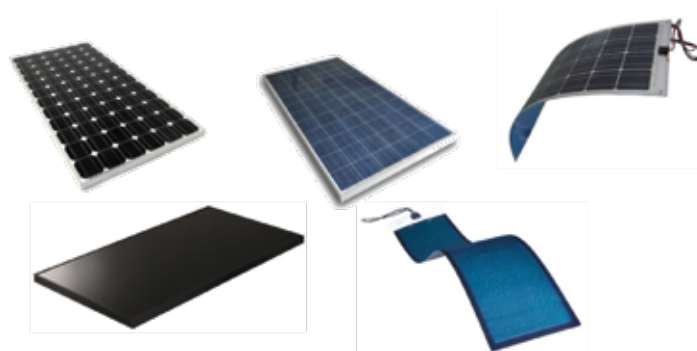
There are many different makes and suppliers of solar PV panels. The vast majority of roof-mounted and ground-mounted solar installations use polycrystalline and monocrystalline silicon PV panels mounted into aluminium frames. Due to their low cost and wide availability, these are often used in solar car parks. However, the design requirements of solar carports are more demanding than that of ground mount and rooftop PV systems and can lead to the use of other panel formats such as laminated frameless panels (two sheets of toughened glass sandwiching a layer of PV cells), semi-flexible and flexible panels (plastic and metal sheets supporting PV cells).

The most widely-sold PV cell technologies are polycrystalline, monocrystalline and thin film. The price and performance of these technologies depends on the local site conditions. However the following performance characteristics should be noted:

- On a south facing site polycrystalline and monocrystalline panels tend to produce greater yields per square metre than thin film. However this difference can be offset by the difference in capital cost, the degradation of output over time and the response to partial shading of the respective technologies.
- Monocrystalline glass laminate panels, comprising of octagonal cells, allow some natural light to penetrate through the panel between the gaps in the cells which can enhance the visual appearance of a solar carport.
- Thin film rigid panels allow for a greater canopy area to be covered by solar panels at a similar cost to rigid crystalline silicon panels due to a lower panel cost per m².
- Flexible panels have lower yields per square meter than rigid glass solar panels and are typically more expensive. Flexible panels are often chosen for architectural or lightweight applications.
- The performance of the latest technologies is constantly evolving, hence choice of technology needs careful consideration in the context of what is appropriate for the design of the installation and the business case.

Lenders are likely to require that developers use tier one panel manufacturers with good financial stability. They should offer at least 20 years linear power degradation warranties of equal or less than 0.8% per year and have deployed a significant amount of capacity in the UK. Bloomberg New Energy Finance publishes a top 10 list of panel manufactures, while developers, banks and financiers have similar white-lists. The use of modular, widely available components allows for cost efficiencies in the procurement chain.

Figure 2 Common PV panel types monocrystalline (top-left) and polycrystalline (top-centre), crystalline silicon on steel sheet (top-right), thin film on glass (bottom-left) and thin film on polymer



Mounting options

The mounting solution connects the solar panels to the carport frame. For PV glazing systems, the mounting solution has the dual role of directing rain water and securing the solar panels. The double roof mounting option uses standard sheet roofing, with standard rooftop mounting clamps securing the panels. The choice of panel, mounting solution and roofing solution are highly interdependent. The visual appearance and the overall cost should be considered comprehensively.



A guttering solution, photo courtesy of EvoEnergy

Electrical design options

All the solar panel string cables (narrow DC cables that connect panels in series) should be concealed. Various methods exist to conceal the cables, such as integrated cable trays and double roof systems.

Inverter options

Inverters perform two purposes: optimising the solar panel Direct Current (DC) output through an internal device called a Maximum Point Power Tracker (MPPT) and converting the generated electricity into Alternating Current (AC) for feeding into the local electrical grid.

Unlike ground and roof-mounted solar there are fewer locations to safely position inverters and electrical connections, due to public access to the car park. Options include housing large central inverters in a dedicated building or using smaller string inverters that fit inside steel housings spaced every 20 car parking bays. Inverter sizes of between 40-100kWp are physically small enough to fit within most carport frames.

If there is some minor shading on the solar panels from trees or adjacent buildings, it is advisable to select an inverter with multiple MPPTs. If there is more significant shading, then it can be worth considering micro inverters (single MPPT inverters connected to the back of each PV panel that convert DC to AC electricity at the module), or DC optimisers (which provide an MPPT behind each panel, but convert DC to AC electricity centrally at an inverter), these are sometimes sold as a packaged 'smart' or 'AC' solar panel. Where there is little or no shade, string inverters (with a single MPPT handling each solar carport array) can be highly efficient. The optimum electrical layout is site-dependent.

Data and monitoring

Monitoring is becoming a standard requirement in the industry. This can be performed at string level via the inverters or at an individual panel level. Data is communicated remotely to local site maintenance or off-site operations and maintenance contractors. EV chargers may also require a data connection to monitor charging, so it is worth considering this aspect early on in the project.

BREEAM implications on solar carports

BREEAM (Building Research Establishment Environmental Assessment Method) is the world's leading sustainability assessment method for infrastructure and buildings. The BREEAM assessment process evaluates the procurement, design, construction and operation of a development on a scale of Pass, Good, Very Good, Excellent and Outstanding. When connected to a building, a solar carport can contribute towards the BREEAM rating of the building.

BREEAM criteria are designed to avoid setting prescriptive requirements; instead they are intended to be outcome-focussed. For example, in terms of energy, BREEAM will typically reward the total reduction in CO₂ emissions, rather than being prescriptive about how the CO₂ emissions savings should be achieved. As such, solar PV can contribute to achieving BREEAM credits in the energy category,

although the same credits could be achieved by using alternative design options. Typically, solar PV installations are eligible to contribute towards credits relating to the following areas:

- Reduction of energy and carbon emissions (these credits are highly-weighted in the BREEAM scoring assessment and are assessed on a reduction against a baseline assessment of energy performance)
- Energy monitoring – i.e. separate metering of system performance for solar PV

These general provisions cover a number of BREEAM certification schemes including New Construction, In-Use and Refurbishment and Fit-Out.

Planning permissions

Planning fee clarification

Solar carports are classified as Erection/Alterations/Replacement of plant and machinery incurring a fee of £385/0.1 hectare (or part thereof). There have been examples where planning offices have mis-categorised planning applications and sought to charge a higher fee. Should this occur it should be challenged, making reference to previous carport application fees, information on which will be in the public domain.



A carport on the roof of a multi-storey carpark in Poole.
Photo courtesy of Batchelor Electrical

Planning application

It is advisable to seek pre-planning advice early during the project, for confirmation of fees and required documents. This is done via a Preliminary Planning Application and it has the benefit of notifying the developer of any complications. Obligatory documents are: site plans, location plan, the planning application form, and design and access statement⁹. The planning application process usually take 8-12 weeks.

In addition to the above documents, additional information may be required by your planning case officers. Solar carport designers should be able to provide the following:

- Specification of the proposed PV panels and EV Charging points
- Structural and foundation details
- Drainage and surface-water management
- Grid connection details
- Glint and glare impacting the surrounding environment
- Details of construction and decommissioning, including associated traffic and compounds for material storage and contractor parking

Local Authorities can use Local Development Orders (LDOs) to streamline the planning application process for specific types of development within a defined area. This may mean that planning permission is not required for a carport project included in an LDO. LDOs create certainty and save time and money for those involved in the planning process.

⁹ This is a document which outlines the design principles and concepts that have been applied to the proposed development and shows how issues relating to access to the development have been dealt with.

Grid connection

Applications to connect a power generating source to the electricity distribution networks are covered by the Energy Network Associations (ENA) Distributed Generation Connection Guides G83/2 or G59/3, depending on the size of the system¹⁰. There are six DNO currently licensed to operate and maintain the grid¹¹ covering geographic regions in Great Britain. Grid connection applications should be made at an early stage, as many projects fail to obtain sufficient connection capacity at a cost which makes them financially viable. Some areas of

the distribution network have become saturated with generation and cannot accommodate any more without costly and time consuming reinforcement. Other areas of the distribution network, however, still have capacity for new generation connections. The IET Code of Practice for Grid Connected Solar Photovoltaic Systems (IET Solar PV CoP) gives detailed advice on the grid connection procedure.

Carport regulation

This section discusses the regulations and standards relating to the major components of solar carports and their interactions with users. It aims to provide potential solar carport owners and developers with a framework for verifying good design practice, and to highlight areas of ambiguous legislation.

PV system standards

Recommended good practice is to design, install and operate solar installations to meet the requirements of the IET Solar PV CoP¹². This document sets out industry accepted good practice for the electrical design of solar PV systems and is aligned with international standards. The scope includes systems up to 50MW and topics covered include: system performance, electrical design, lightning protection, network connection, high voltage systems, system monitoring, battery systems, fire risks, health and safety, system commissioning, and operation and maintenance. It is recommended that the IET Solar PV CoP is stipulated as a requirement during the procurement process.

Structure regulations

Carports are classified as buildings and must fulfil Building Regulation Part A: Structure. This document identifies the relevant legislation relating to the building materials and methods proposed for a canopy design. The land owner is ultimately responsible for complying with the relevant planning permissions and building regulations and will be liable for any remedial action.

Construction Products Regulations

The Construction Products Regulations 2011 (CPR) requires that manufacturers apply CE markings to any of their products which are covered by European Standards (EN) or European Technical Assessment (ETA). This is a major change for the UK construction industry as previously CE marking was voluntary and has a particular relevance to frame manufactures. Responsibility for ensuring that a product has the correct characteristics for a particular application rests with the designers, contractors and local building authorities.

Wind loadings

BS EN 1991-1 Eurocode 1: Actions on structures states the wind loadings specific to the UK. These often exceed EU requirements, and so care should be taken to ensure overseas designs meet UK building regulations.

Impact from vehicles

Canopies 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.

Design Life

It is advisable to use a structure with a design life of at least 20 years. This is in line with FIT incomes (if available) and solar panel warranties.

Overhead glazing regulations

Regulations regarding the use of glass in carport structures are specified in Building Regulation K: Protection from falling, collision and impact. The regulations place greater emphasis on the safety requirements of glazing with which people can physically impact.

The choice of glazing system should also conform to BS 5516-2:2004 Patent glazing and sloping glazing for buildings. This is not a standard, but a voluntary code of practice for sloping glazing which stipulates the mechanical design and wind loading of PV glazing solutions.

Carport solutions that do not require people to access the roof canopy during the construction and maintenance phases are preferable. This can be achieved by use of mounting solutions that give access to panels from underneath the canopy. This avoids the roof being classified as fragile by removing any human loads that can be reasonably thought to occur. No access to the roof also protects the PV panels from damage which could lead to panel underperformance or an electrical fault.



Signage on a carport, photo courtesy of EvoEnergy

¹⁰ For more information go to <http://www.energynetworks.org/electricity/engineering/distributed-generation/dg-connection-guides.html>

¹¹ For a map, see <http://www2.nationalgrid.com/UK/Our-company/Electricity/Distribution-Network-Operator-Companies/>

¹² <http://www.theiet.org/policy/media/press-releases/20150916.cfm>

Lighting regulations

Car park lighting levels are specified in BS 5489-1:2013 Lighting of roads and public amenity areas. The objective is to enable users to proceed safely and allay the fear of crime. This specifies a minimum of 10 lux for sites of medium traffic (e.g. department stores, office buildings, plants, sports centres). However, this guide recommends 20 lux, in line with the British Parking Associations (BPA) Park Mark. Under-canopy lighting is suggested in order to maintain uniform lighting in the aisles, bays and between cars. This promotes a sense of security for car park users and also protects against legal liability for claims resulting from vehicle collisions at low light levels. It is also recommended that light be contained within the general curtilage of the car park to save energy and avoid light pollution.

Drainage regulation

Car parking drainage is specified in Building Regulation Part H: Drainage and waste disposal. The emphasis of these regulations is on structural integrity and rain water disposal. As such, the carport guttering system must be able to dispose of peak rainfalls to prevent the build-up of weight on the roof.

A gutter or eaves drop system has the function of protecting the structure from rain water runoff from the roof. An eaves drop system has no gutter and allows rain water to fall to the ground, while a gutter system has the added important benefit of protecting car park users from dripping and splashing rain water.



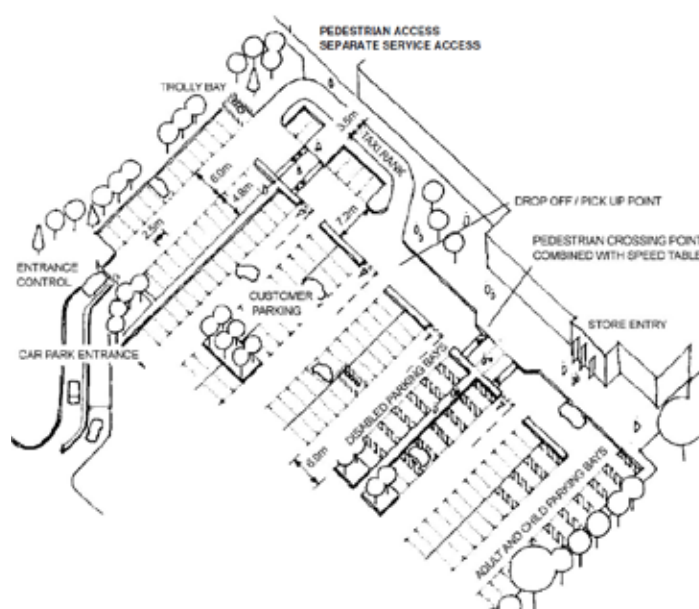
Guttering attached to a downward column
Photo courtesy of SunGift Energy

Rain water pipes should discharge into either a drain or onto the car park surface. Existing car parks should have sufficient drainage capacity, as this would have been an original design requirement. Carports have no effect on the drainage requirement of the car park as they do not vary the total amount of rain water falling onto the car park surface. Allowing the water to discharge onto the surface of the car park from the footer of a downpipe is the preferred solution for solar carports, due to the prohibitive cost of connecting to below-ground drainage. Typical rainfalls will not cause excessive streaming of water if down pipes are placed at intervals of 6-10 car parking bays.

Car park layout regulations

Parking layouts are issued by local government and many refer to the Manual for Streets Published by the Department of Transport. This gives standard bay dimensions of 2.4m width, 4.8m depth and aisle widths of 6m. Typically, bay widths vary between 2.2m to 2.6m, depending upon the car park function as illustrated in figure 3. Short stay car park bays under frequent use are wider than long stay car parks under light usage. Parent and child bays are 1.5 times the width of a standard bay, while disabled bays are two times the width. In most cases bay markings will already be in place and car park owners will not want to modify them. If bay line markings cannot be modified then it is advisable to choose a car park frame design that can accommodate varying bay widths.

Figure 3 Examples of parking arrangements¹⁴



Park Mark – The Safer Parking Scheme

The Safer Parking Scheme is managed by the BPA and is a voluntary standard for UK car parks that have low crime and measures in place to ensure the safety of people and vehicles. Each car park undergoes an assessment by Police Architectural Liaison Officers who evaluate criteria such as lighting, pedestrian and vehicular access, surveillance and signage. Over 5000 car parks have been awarded the Park Mark. Car park owners considering solar carports at sites currently not meeting Park Mark criteria should speak with their BPA Area Manager if they wish to be reassessed. Details available at www.britishparking.co.uk



The Park Mark logo, image courtesy of BPA

¹⁴ http://publications.1fife.org.uk/uploadfiles/publications/c64_Chapter7.pdf

Procurement

Public sector

The public sector must use tendering processes compliant with the Official Journal of the European Union (OJEU) for projects exceeding the current cost threshold of £111,000. Completing an OJEU tender takes time, money and resource, and several organisations operate OJEU-compliant frameworks that reduce the administrative requirement of tendering by offering a list of pre-accredited suppliers. Councils not operating under any existing framework and with sufficient internal expertise may wish to directly procure a carport developer. Some examples of existing procurement routes are shown below.

Public Power Solutions (PPS) is wholly-owned by Swindon Borough Council and is therefore classed as a contracting authority. It developed the UK's first Dynamic Purchasing System¹⁵ (DPS) compliant with the new Public Procurement Directive (2014/24/EU) and OJEU, designed to enable public sector bodies to successfully procure all of the services needed to develop solar projects. The DPS has pre-accredited suppliers in place and is open for new suppliers throughout the Contract Notice life. A typical procurement using the DPS can prepare, publish, score, recommend and award a contract within a shorter timeframe than other procurement routes. DPS suppliers have been pre-accredited on areas of financial stability, health and safety, insurance, accreditations, experience and pricing. PPS can provide solar development services at no cost to the client and will take the development risk and manage the development from inception to completion.

RE:FIT¹⁶ provides a commercial model for public bodies wishing to achieve substantial financial cost savings, improve the energy performance of their buildings and reduce their CO₂ footprint. Energy Service Companies (ESCOs) implement the energy efficiency measures and guarantee the level of energy savings over an agreed payback period, thus offering a secure financial saving over the term of the agreement. To benefit from the RE:FIT scheme the public sector body should identify the solar carport project as an Energy Saving Measure (ESM) and bring it to the attention of the local RE:FIT Programme Delivery Unit (PDU).

Private sector

Large private sector organisations often have delivery partners for facilities management, construction and more specifically commercial rooftop PV systems. There are many companies that offer commercial rooftop systems, however, one should ensure that such companies' experience includes the complex project management skills required in solar carport installation. Even large nationwide contractors tend to subcontract much of their solar carport design and delivery to specialists.

Typical timescales

Before breaking ground several months of preparatory work is required. Obtaining planning permission requires a statutory minimum of 6 weeks and an application for a G59/3 grid connection can take up to 90 days. If significant upgrades to the local power infrastructure are required, such work may take several months to complete. Both the grid connection G59/3 application and pre-planning advice can be undertaken simultaneously, and often a G59/3 application is requested by the developer at the earliest opportunity. Timescales for the actual installation are site specific as they will vary considerably depending on the complexity of a site and its restrictions. However a straightforward, surface carpark installation of 500 carport bays (1MWp) can be completed in less than 4 weeks of onsite work.



Installation of a carport, photo courtesy of SunGift Energy.

Conclusion

Solar car parks are established in both the US and EU markets. It is hoped that this good practice guide provides the industry and car park owners with the information to develop the UK solar car park market to the same level as that seen abroad.

¹⁵ <https://publicpowersolutions.co.uk/services/public-sector-dynamic-purchasing-system>

¹⁶ <http://refit.org.uk/>

Case studies

Schletter GmbH company car park, Oberbayern, Germany

260 parking bays, 500kWp capacity
Developed and owned by Schletter GmbH

Schletter is a manufacturer of solar mounting systems. It has taken the opportunity to use its own car park as a showcase for its products and carport design options. The construction of the carports took 3 weeks and was carried out without interrupting production. The system uses the Park@Sol mounting system, in which small pre-cast concrete foundations are anchored onto micro-piles. This entails minimal construction works on the car park surface and is suitable for almost any type of subsoil.

The additional output from the carport complements that from the PV installation on the factory roof, and is consumed onsite with excess used for EV charging or exported to the grid.



Photo courtesy of Schletter

Mary Arches and John Lewis car parks, Exeter City Centre

144 parking bays, 300kWp capacity
Owned by Exeter City Council, developed by SunGift Energy

Completed in September 2015 by SunGift Energy, these were the first solar carports to be installed on the top decks of multi-storey car parks in the UK. PV systems have been installed on other multi-storey car parks in the form of a Portal-frame canopies covering the entire the top deck.

The PV systems combined capacity is 300kWp and they cover a total of 144 car parking bays. The owner, Exeter City Council, benefits from more usable car parking spaces, FiT payments and energy bill savings. The projects generate around 285,000kWh of electricity annually and provide solar power to the free public electric vehicle charging points in the car parks.

There were some significant structural challenges due to the age and construction of the car park decks, which required SunGift Energy to design bespoke carport frames. Construction was managed such that all of the other decks of the car parks remained operational throughout the installations.



Photo courtesy of SunGift Energy

Harvey Hadden Sports Village, Nottingham

40 parking bays, 67kWp capacity
Owned by Nottingham City Council, developed by EvoEnergy

Completed in September 2015 by a collaboration between Evoenergy, The Solar Cloth Company, Sitec Infrastructure Services and with design expertise from Flexisolar. This represents the first use of rigid thin-film panels on a partially-shaded, north-west facing aspect, overcoming the limitations of silicon technology.

PV system capacity is 67kWp, comprising 448 TSMC copper indium gallium selenide (CIGS) thin-film solar panels covering 40 car parking bays. The steep incline of the site, required eight individual stepped structures spanning 5 bays each. The solar panels are conventionally mounted on Clenergy rails above a trapezoidal roof. The carport is eligible for the FiT and generates over 50,000 kWh per annum, most of which is consumed onsite by the main sports facility.

The installation was part of a £16m redevelopment of the adjacent leisure centre, which also included a number of other energy efficiency measures. This will help meet the council's ongoing commitment to reduce carbon emissions by 26% by 2020.



Photo courtesy of EvoEnergy

Ken Martin Leisure Centre, Nottingham

41 parking bays, 88.5 kWp capacity
Owned by Nottingham City Council, developed by EvoEnergy

Completed in February 2016 by EvoEnergy. The PV system is 88.5kWp and covers 41 car parking bays, split between 9 separate structures. The layout of the site was complex and care was taken to plan access for buses and high-sided vehicles between the carports.

The carport roofs face multiple directions, making the electrical connection of the PV arrays challenging. The PV system features conventional silicon panels connected fitted with DC optimisers which act to balance the differing performance of each panel. Whereas the traditional design limits all modules in the string to the output of the lowest, this system allows pairs of panels to communicate directly to the inverter through a real-time monitoring system. In the event of one panel losing efficiency, only two from the array will be affected. In the event of a fire or broken cable, the power supply will drop from 750V to 21V.

All power produced is expected to be used on-site and the system should reduce Nottingham City Council's carbon footprint by over 42 tonnes of CO₂ per year. The financial payback is expected to be 11 years.

As an install, the two-phase project posed a number of challenges which, while not unique among buildings which serve the public, required special efforts from the on-site team. This included efforts to minimise disruption during car park closures in the run up to Christmas and using ropes and scissor lifts to avoid any danger to the public during the panel fitting process.



Photo courtesy of EvoEnergy

Cambridge Research Park, Cambridge

15 parking bays, 15kWp capacity
Owned by Cambridge Research Park, developed by The Solar Cloth Company

Completed in April 2014 by The Solar Cloth Company with installation support from Flexisolar this is the first tensile membrane carport in the UK. The PV system is 15kWp and comprises of 75 Global Solar flexible modules bonded to the tensile membrane. The design also incorporates two EV charging points integrated into the vertical frame.

The Solar Cloth Company overcame several design challenges and delivered an aesthetically striking design; with Flexisolar completing the installation by providing expertise in the tensile membrane installation, and providing the PV module bonding expertise.

The owners commented that "We love the product and are excited to be the first in the UK, and of course I think it was well worthwhile to install such a striking car-parking structure. Sometimes it is not about the financials but about the beauty and the simplicity of the idea, and the belief in the commitment to green energy."



Photo courtesy of The Solar Cloth Company

Hoffenheim Football Stadium, Sinsheim, Germany

450 parking bays, 1000kWp capacity
Owned Hoffenheim football club, developed by Wircon

Completed in 2014 by Wircon, this is one of the largest solar carports in the EU.

The PV system is 1MW, comprising of 47 SolarEdge inverters and 2,013 SolarEdge power optimizers connecting 4,025 PV panels. The fixed-string voltage of the SolarEdge inverter allows for a more flexible system design and longer strings for decreased balance of system costs.

The 1MW carport PV system consists of 4,025 solar panels, and produces almost 1.1 GWh hours of electricity per year. This corresponds to about two-thirds of the electricity demand of the arena



Photo courtesy of SolarEdge Technologies

Manor Farm, Fenstanton, Cambridgeshire

6 parking bays, 10kWp capacity
Owned by Manor Farm, developed by Flexisolar

Completed by Flexisolar in February 2016 as a low-cost, scalable carport system for deployment onto large surface car parks. The carport has one of the lowest costs of deployment in the UK due to several design innovations. The carport is also the first to combine EV charging points and LED under-canopy lighting.

The PV system is 10kWp covering 6 car parking bays. The carport is the first in the UK to feature an integrated, watertight PV-glazed roof that is fully compliant with UK Building Regulations and represents a significant cost saving over double-roof carports. The PV panel mounting can accommodate all PV panel types, allowing installers a wide choice of PV panel supplier.

The V-framed duopitch variation shown here can be deployed in single or double bay formation to cover many types of layout on either surface or multi-storey car parks.



Photo courtesy of Flexisolar

Garden City Shopping Mall, Nairobi, Kenya

454 parking bays, 858kWp
Developed by Solarcentury

Solarcentury designed and constructed this hybrid solar carport system on the uppermost storey of a car park at Garden City Mall, part of the new 32-acre integrated residential, retail park, hotel and office development on Nairobi's Thika Superhighway.

The solar electricity it generates is used by the retail tenants to power facilities such as the lights and escalators in the mall. The solar carport is powerful enough to power 550 urban homes in Nairobi every year.

As well as providing shade, the 3,300 solar panels on the carports will generate 1,256 MWh per year, and cut carbon emissions by around 745 tonnes per year. The solar hybrid technology is a highly innovative energy solution that provides solar energy in the daytime, meaning less is used from the grid; and when the grid is down, the system also reduces the consumption of costly diesel back up. Essentially, the system is able to operate in either mode. This solar hybrid system ensures a consistent energy supply whilst reducing diesel and grid consumption, so as well as being a more environmentally friendly energy solution, it helps reduce energy bills for Garden City's retail tenants.



Photo courtesy of Solarcentury

BRE Trust

The BRE Trust uses profits made by BRE Group to fund new research and education programmes, that will help it meet its goal of 'building a better world together'.

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